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OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

W. F. KING
Chief Astronomer
Ottawa

R. F. STUPART
Director of the Meteorological
Service of Canada, Toronto

J. S. PLASKETT
Dominion Observatory
Ottawa

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Editorial communications should be addressed to C. A. Chant, University of Toronto, Toronto, Ont.

Business correspondence, remittances, etc., should be addressed to Chas. P. Sparling, Treasurer of the Society, 11 Biscarth Rd., Toronto.

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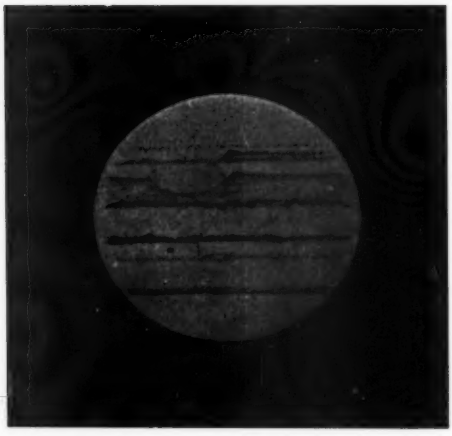
PLATE V.

S

E



W

JUPITER, MAY 11, 1909

Lowell Observatory — Drawing by Percival Lowell

S

E

W

JUPITER, 1907

Lowell Observatory — Drawing by E. C. Slipher

PLATE VI.

S

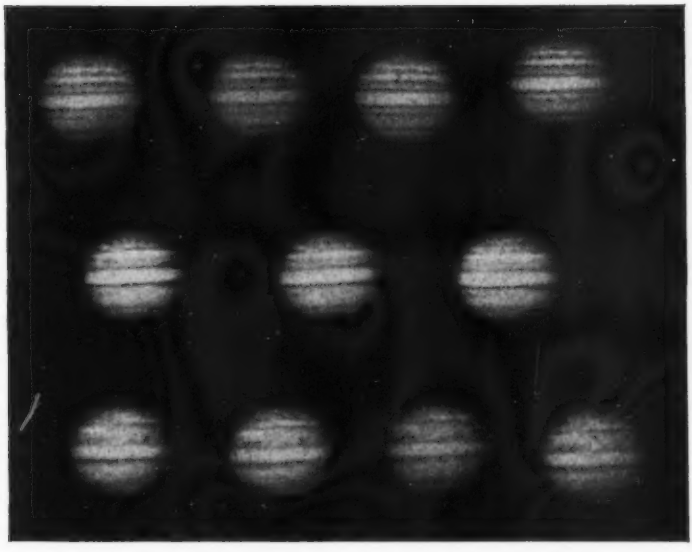
I.

E

II.

W

III.



N

FROM PHOTOGRAPHS OF JUPITER TAKEN AT THE LOWELL OBSERVATORY, 1909

I. April 26d 8h 26m
II. April 27d 7h 45m
III. April 27d 9h 55m

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. IV. MARCH-APRIL, 1910. No. 2

PHOTOGRAPHS OF JUPITER.

MADE AT THE LOWELL OBSERVATORY, 1909.

BY PERCIVAL LOWELL

THE photographs of Jupiter, of which this paper is the libretto, were made at this observatory this spring between the dates March 10 and May 20 by Mr. E. C. Slipher and the Director. Ones earlier in the opposition were also obtained, which are not included specifically in the paper, as well as many others taken during the interval included. Those here presented by prints and those of which the measurements are given in the text will convey the best general idea of the work.

By way of preface I may perhaps call attention to the delicacy of the detail shown in the reproductions. For the prints are enlarged $\frac{150}{82.5}$ times, or to nearly twice the size of the original plates. Nevertheless they hardly show it, judged by any loss in definition, and furthermore permit of measurement to some degree of accuracy. The fading-off of the light at the limbs and also at the poles will be noticed. This local falling-off in illumination is inherent in the planet but the contrast is intensified by the photographic plate; in some ways an advantage as it renders difference of albedo the more noticeable. As the plates

used were Cramer's Instantaneous Isochromatic, and a color screen, cutting off all the rays of shorter wave-length than $\lambda = 5000$, was interposed before the plate, the effect was practically that of the yellow rays. For these plates have a sharp rising curve of intensity from $\lambda = 5000$ to the yellow, falling off again into the red. The result with the screen is a sensitiveness nearly corresponding to that of the eye. The present photographic process, therefore, not only gives much more definition than previous ones but gives in addition values to the tones much more in keeping with those of visual observation.

The first point we may consider is the arrangement and disposition of the belts. For the belts are Jupiter's sign-manual of his physical condition. Whoso reads aright, will decipher Jupiter's present state. Measures of the positions of the belts from images on the plates are as follows :

Plate (1) March 10 $12^h : 15^m - 40^m$ E.C.S. $\lambda = 276°$ System II

		cor. for tilt = − 1°·5	Corrected
	°		°
S.	− 39·9	N. line in S. Hood	= − 41·4
	26·7	S. Temp. belt	28·2
	16·5	S. edge of S. Tropic belt	18·0
	6·2	N. " " " "	7·7
N.	+ 11·7	S. " N. " "	+ 10·2
	20·5	N. " " " "	19·0
	37·1	S. line below N. Hood	35·6
	52·7	N. Hood	51·2

Plate (2) March 15 $11^h : 17^m - 11^h : 32^m$ E.C.S. $\lambda = 342°$ II

		cor. for tilt = − 1°·4	Corrected
	°		°
S.	− 38·4	line N. of S. Hood	= − 39·8
	25·2	S. Temp. belt	26·6
	14·5	S. edge of S. Tropic belt	15·9
	6·4	N. " " " "	7·8
N.	+ 12·4	S. " N. " "	+ 11·0
	25·7	N. Temp. belt	24·3
	38·6	line S. of N. Hood	37·2
	54·1	N. Hood	52·7

Plate (3) April 14 P.L. $\lambda = 82° \pm$ II

cor. for tilt = $-1°{\cdot}3$ Corrected

	°		°
S.	−37·2	line below S. Hood	= −38·5
	27·6	S. Temp. belt	28·9
	19·5	S. edge of S. tropic belt	20·8
	15·9	dark line in S. tropic belt	17·2
	6·8	N. edge S. tropic belt	8·1
N.	+ 9·4	S. edge N. tropic belt	+ 8·1
	17·8	N. " " " "	16·5
	35·0	N. Temp. belt	33·7

Plate (4) April 23 $8^h : 10^m - 30^m$ E.C.S. $\lambda = 262°$ II

cor. for tilt = $-1°{\cdot}25$ Corrected

	°		°
S.	−38·0	line N. of S. Hood	= −39·2
	27·0	S. Temp. belt	28·2
	15·9	S. edge of S. Tropic belt	17·1
	6·8	N. " " " "	8·0
N.	+11·0	S. " N. " "	+ 9·8
	20·4	N. " " " "	19·2
	37·6	line S. of N. Hood	36·4
	50·3	N. Hood	41·1

Plate (5) April 26 $7^h : 20^m - 32^m$ E.C.S. $\lambda = 321°$ II

cor. for tilt $-1°{\cdot}2$ Corrected

	°		°
S.	−41·5	S. Hood	= −42·7
	35·8	line N. of S. Hood	37·0
	25·5	S. Temp. belt	26·7
	15·2	S. edge of S. Tropic belt	16·4
	6·6	N. " " " "	7·8
N.	+10·7	S. " N. " "	+ 9·5
	21·0	N. " " " "	19·8
	37·4	line S. of N. Hood	36·2
	48·6	N. Hood	47·4

Plate (6) April 27 $7^h : 45^m$ E.C.S. $\lambda = 123°$ II

cor. for tilt $-1°{\cdot}2$ Corrected

	°		°
S.	−39·4	line below S. Hood	= −40·6
	28·9	S. Temp belt	30·1
	18·9	S. edge of S. Tropic belt	20·1
	7·8	N. " " " "	9·0

Plate (6) April 27 (*Cont.*) $7^h : 45^m$ E.C.S. $\lambda = 123°$ II

N. +10·8	S. edge of N. Tropic belt	+ 9·6
37·5	line S. of N. Hood	36·3
49·5	N. Hood	48·3

Plate (7) May 5 $7^h : 42^m - 54^m$ E.C.S. $\lambda = 245°$ II

cor. for tilt − 1°·2 Corrected

°S. −36·9	line N. of S. Hood	= −38·1
25·3	S. Temp. belt	26·5
15·4	S. edge of S. Tropic belt	16·6
6·4	N. " " " "	7·6
N. +12·0	S. " N. " "	+ 10·8
19·8	N. " " " "	18·6
38·9	line S. of N. Hood	37·7
54·0	N. Hood	52·8

Plate (8) May 8 $9^h : 27^m - 45^m$ P.L. $\lambda = 0°$ II

cor. for tilt − 1°·2 Corrected

S. −42·9	S. Hood	= −44·1
34·7	line N. of S. Hood (absent but present farther E.)	35·9
26·7	S. Temp. belt	27·9
15·7	S. edge of S. Tropic belt	16·9
6·5	N. " " " "	7·7
N. + 8·2	S. " N. " "	+ 7·0
18·1	N. " " " "	16·9
32·9	line S. of N. Hood	31·7
44·5	N. Hood	43·3

Plate (9) May 11 $8^h : 5^m - 22^m$ P.L. $\lambda = 82°$ II

cor. for tilt − 1°·2 Corrected

S. −47·5	S. Hood	= −48·7
37·6	line N. of S. Hood	38·8
26·9	S. Temp. belt	28·1
18·5	S. edge of S. Tropic belt	19·7
5·7	N. " " " "	6·9
N. +11·9	S. " N. " "	+10.7
23·3	N. " " " "	22·1
39·8	line S. of N. Hood	38·6
53·1	N. Hood	51·9

Plate (10) May 17 $8^h : 4^m$ E.C.S. $\lambda = 262°$ II

cor. for tilt $- 1°{\cdot}2$ Corrected

	°		°
S.	−45·0	S. Hood	= −46·2
	36·4	line below S. Hood	37·6
	25·5	S. Temp. belt	26·7
	14·7	S. edge of S. Tropic belt	15·9
	6·7	N. " " " "	7·9
N.	+10·0	S. " N. " "	+ 8·8
	18·7	N. " " " "	17·5
	36·9	N. Temp. belt	35·7
	49·1	N. Hood	47·9

Plate (11) May 20 $7^h : 38^m - 51^m$ E.C.S. $\lambda = 326°$ II

cor. for tilt $- 1°{\cdot}2$ Corrected

	°		°
S.	−41·0	S. Hood	= −42·2
	36·2	line below S. Hood	37·4
	25·6	S. Temp. belt	26·8
	15·3	S. edge of S. Tropic belt	16·5
	6·2	N. " " " "	7·4
N.	+10·3	S. " N. " "	+ 9·1
	19·3	N. " " " "	18·1
	34·2	N. Temp. belt	33·0
	45·5	N. Hood	44·3

These measures of the positions of the belts from prints of the particular plates taken between March 10 and May 20, 1909, show that the width and the latitude of the same belt varies somewhat with the longitude on the planet. The centre of the equatorial bright belt lies a little to the north of the equator as a rule, though in longitude 0 (system II) it actually runs a little to the south of it. The bright belt in the clear is about 13° wide while the tropic belts on either side are about 12° across. Between longitude 180° and 260° the duskiness which now fills almost completely the south tropic belt expands through the whole distance to the south temperate belt which lies in latitude 27° – 28° eliminating in so doing the south edge of the tropical belt.

A very different condition is now shown by the north tropic dark belt. Like the south tropic one this consists of two dark

fringing strips ; but, unlike the southern belt, the edge farthest from the bright equatorial belt fades out in certain longitudes leaving only the stripe on the south. In no place is the space between the fringing edges filled with duskiness and nowhere does the belt invade the temperate one to the north of it.

The north temperate belt properly speaking is lacking, an absence which adds to the relatively light tone of the northern hemisphere. Its place, is in part supplied by the belt below the polar hood which we may perhaps call the arctic belt though it occurs in latitude 32° – 37° according to the longitude. The corresponding antarctic line is in 37° – 39° of latitude. Dusky hoods cover both poles. They may be said to begin from 42° to 53°, north or south, dependent on the longitude, and stretch thence continuously to the pole. Both present a stippled effect in marked contrast to the striped character of the rest of the disk. In this they curiously recall the ground pattern of the sun. The absence of striation in the planet's higher latitudes side by side with the marked banding in lower ones is a phenomenon of which later in the paper I shall suggest a possible cause.

With regard to the detail disclosed on the plates, the most important and interesting is the registration of the wisps lacing the bright equatorial belt. These wisps as such were discovered, I believe, by Mr. Scriven Bolton, and as they had never been definitely seen elsewhere they were sent to the Lowell Observatory for confirmation or otherwise. They were found visible there as soon as the planet was critically observed, and then were actually registered on the photographic plate, which, considering their faintness, speaks for the detail the new method of planetary photography is able to register.

In look, they are most curious phenomena. They consist of a very remarkable set of irregular narrow dark streaks proceeding from triangular black spots in the northern edge of the south tropic dark belt and running thence, usually at an angle of 45°, to similar spots in the southern edge of the north tropic one. Their appearance is best likened to the distant dropping of rain from a summer cloud seen two or three miles away. Though at

equal angles to both belts, their direction is not always that of 45° but at times is nearly perpendicular to their departure points. They are numerous and fairly well distributed round the longitudes. What they betoken is an interesting enigma. That they denote the absence rather than the presence of something seems self-confessed. For the bright belt is clearly cloud and these dark filaments must be rents in it, not entities in themselves. They would seem to betoken, therefore, currents setting across the equator of great force and persistency. The spin of the planet combined with their own motion may explain their inclination.

Such may also account for the dark medial thread which bisects nearly longitudinally the bright equatorial band.

Wisps or lacings are not confined to the bright equatorial belt. They are found across the other bright belts as well. A set of photographs by Mr. E. C. Slipher on April 26, 1909, shows two prominent ones between the south polar hood and the south temperate belt, the two straddling the centre of the disk and thus in longitude 310° II and 330° II. Others between the south temperate and south tropical belts stand out on photographs by the Director on May 11—approximately in longitude 60° II, 80° II and 100° II. These are merely samples of what may be seen on the plates.

Another noteworthy feature of the belts is the paired propensity of the tropic ones. This results from a darker tone at their edges than in between. At their maximum intensity the effect is but slightly noticeable ; then as the belt fades it does so first in the centre until the mid-ground is almost as light as the brighter stripes of the disk. That the action is an index of a physical condition is evidenced from the fact that Saturn shows the like arrangement.

It seems that we should regard the dark belts as being openings in the cloud strata composing the bright belts. The reasons for this are as follows. In the first place the planet's albedo, according to Müller who has made the latest determination of it, is 0·75. Now that of cloud is 0·72. The one is so near the

other as to leave but little margin for any intrinsic light from Jupiter himself. Now the bright belts are a great deal more luminous than the dark ones as the photographs themselves evidence. The dark belts, therefore, cannot be cloud, while on this testimony alone the bright ones may well be.

In the next place all the dark parts of the planet show cherry-red, faintly toward the poles, pronounced in the tropic belts. Now the mean density of the planet, 1·32 times that of water, considered in combination with his surface gravity, which after allowing for his rotation amounts at his equator to 2·31 times that at the earth's, shows that the planet must be intensely hot, for otherwise gravity would have condensed his matter to something exceeding the earth's mean density which is 5·527 times that of water. Knowing thus that the planet must be hot, the cherry-red of the dark belts stands explained. They show this tint because the matter there is red-hot. Thus the intrinsic heat and the apparent lack of self-luminosity stand reconciled. The planet is red-hot but not white-hot. And since it must be hotter within than without, the cherry-red belts must lie at a lower level than the bright yellow ones. In addition we may note that if the dark belts were cloud they could not in albedo fall below that of cloud—which they do—however much they might exceed it by reason of their own glow. For it must not be forgotten that clouds seen from without are much brighter than when seen as we see them commonly from below. A cloud-surface looked down upon from a balloon out of a clear sky resembles polar ice for whiteness, as the writer has himself observed. We should, therefore, expect clouds seen from without, as we see them on the major planets, somewhat to exceed the standard cloud albedo, enough to make up for the amount the dark belts fall below it. This is precisely what Müller's determinations make out to be the case.

With this much of ground for our premises we may proceed to deductions. The wisps, in the first place, cannot be entities but lacunæ, gaps in the cloud stratum they seemingly cross. Why the cloud belt should be thus broken up we may not readily

understand, but our own mackerel sky may suffice to show us that a tessalated structure is quite compatible with a general belt of disturbance. To attempt to understand it we may notice the forces necessarily at work.

The first in appearance, which is really the last in order, is the swift rotation of the planet, a speed roughly 27·5 times our own at the equator or 27,500 miles an hour, equivalent to seven and a half miles a second. Such a velocity could not but shred any seethings from below into long latitudinal filaments unless their own speed of ejection were enormous. It also explains why the belts disappear toward the poles, giving only intermittent broken effects beyond latitude 50° and ceasing entirely at higher ones. Thus the banded appearance of Jupiter goes hand in hand with his latitudinal rotation spin.

The second factor is the seething circulation in the mass. The heat must produce convection currents in the fluid which, inasmuch as the heat gradient does not correspond to the distance from the centre being clearly more rapid toward the poles of the spheroid than toward the equator, would produce disturbances, seethings and sinkings, according to the latitude.

A third factor is the intrinsic difference in the rates of rotation of different parts of the mass. The fact that particles at the equator, revolve faster than at the poles has been shown to be the lingering effect of the motions of the particles by which the mass was formed. This fact must have its effect in forming the planet's present belts. . This factor occurs also in the case of the sun and, as we know, the disturbances occur in definite latitudes, the spot belts. The case of Jupiter does not exactly parallel that of the sun because of the swift rotation of the one body and the leisureliness of the other. That the belts have no appreciable dependence on the sun, but are caused by the planet's own ebullient condition combined with his rapid axial rotation is evident from their longitudinal regularity. Were the sun the cause of commotion, the poles and the equator would be the antipodes of the action and the currents set up from the one to the other would then be affected by the rotation as they are on earth to a

wavily up and down spiral motion. The level disposition of the belts proves that the cause is not a pole-equator one primarily but a central one, the belt features being due to the rotation, directly in the first place, indirectly in the second to the flattening of the globe which they produce.

We thus see that Jupiter is in a midway state between sun and world. He has in consequence the special characteristics of neither. Not shining perceptibly, if at all, by his own light, which is but a brick-red glow at best, he lacks the essential quantity of a sun, luminosity. No less he fails as yet of those conditions which enable a mass of planetary matter to evolve into a world. He is still a seething chaos of indescribable turmoil. Too hot to be the one body, too cold to be the other, he stands between in a state essentially his own. Thus he represents a phase of world-evolution of an interesting and distinctive type, the Jovian era, long precursor to a more mundane one.

LOWELL OBSERVATORY
December, 1909.

A LEAST SQUARE SOLUTION OF THE ORBITAL ELEMENTS OF α DRACONIS

By W. E. Harper

IN a previous paper* were given the elements of the orbit of this spectroscopic binary as determined by the methods of Russell and Lehmann-Filhés and based upon observations made in 1906 and 1907. At that time no attempt was made to correct the elements by the method of least squares, as the observations were not considered of sufficient accuracy to justify such a procedure. Since that time, however, the method has been applied to correct the graphically determined elements of stars, the observations of which were not nearly so trustworthy as those of α Draconis, and the much better agreement between theory and observation attained has amply justified the procedure. Such being the case it was considered worth while applying the method to the orbit of this star. Moreover it has developed in recent work that there are spectroscopic binaries whose elements undergo changes. In order to test whether this was the case in α Draconis, plates of this star have been recently secured and they go to show that no appreciable changes have taken place either in the period or other elements of the star's orbit.

The thirteen plates secured recently, as well as the forty-six earlier ones, were weighted according to their quality and the accordance of the various lines measured and were grouped according to phase into fourteen normal places. Preliminary values for the elements were obtained by the graphical method of Dr. King though these differed slightly from the earlier determinations. The corrections to these from the least square solution were small, the value of Σpvv being lowered, however, from 213 to 146

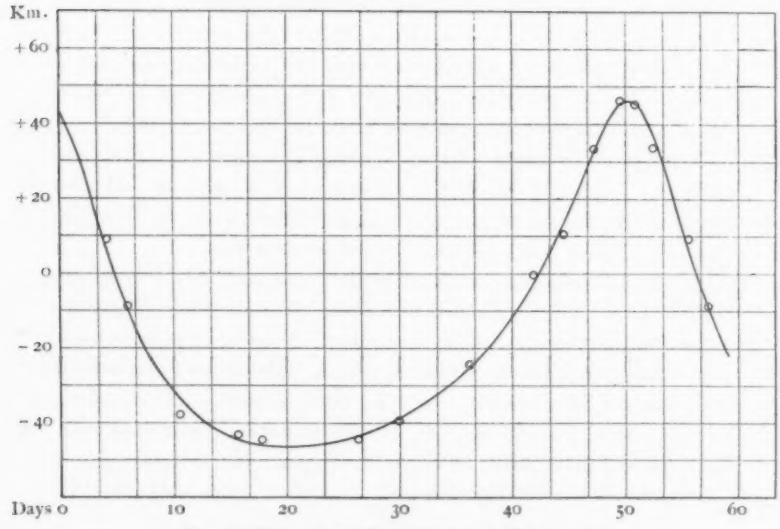
*This Journal Vol. I. No. 4, 1907.

That one solution was sufficient was shown by the small differences in the residuals of ephemeris and equation, the average being ±0·06 km.

The following table gives the mean values of the two determinations in my previous paper, the preliminary values used in this solution and the final elements with their probable errors :

ELEMENTS OF ORBIT

Elements	1906-1907	1909-1910	
		Graphical	Final
	d		d
P	51·38		51·38
e	·43	·41	·384 ± ·003
ω	19° 07′	15°	19° 04′ ± 2° 13′
K	47·5 km.	47 km.	46·25 km. ± ·24 km.
T	J. D. 2,417,403	2,417,403	2,417,403·284 ± ·230
γ	− 16·8 km.	− 17·61 km.	− 17·03 km. ± ·15 km.
A	66·80 km.	65·61 km.	63·03 km.
B	28·20 km.	28·39 km.	29·47 km.
a *sin* i	29,870,400		30,173,000 km.



FINAL VELOCITY CURVE OF α DRACONIS

The curve shown is plotted from the final elements, the points shown being the observations as grouped. The value of the work is simply the securing of closer approximations to the values of the elements and the evidence that these are not varying.

DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA,
February, 1910.

PERSONALITY WITH THE TRANSIT MICROMETER

By R. M. Stewart

Read before Section A of the American Association for the Advancement of Science at Boston, December 27, 1909

ONE of the principal phases of work in which the Dominion Observatory is engaged is the determination of longitudes of various points in Canada. The field instruments, one of which has hitherto been used also for the home observations, are of the ordinary type of Cooke transit, with object-glass of about three inches aperture and three feet focal length. They are equipped with transit micrometers of a modified Sægmuller type; the home instrument records over every alternate four revolutions (of the micrometer screw) throughout the field, the groups of records being distributed symmetrically on each side of the line of collimation; the eye-piece travels at the same rate as the micrometer slide; in the field instruments provision is made for only four groups of records, two on each side of the line of collimation, while the eye-piece does not move automatically.

The instrument is reversed during the observation of each star, the records being taken over the same part of the screw in each position of the instrument. A time set consists usually of three or four north stars at upper culmination, of declinations between 70° and 80°, combined with seven or eight south stars as near to the zenith as convenient; this involves, for the latitude of Ottawa, an average declination for the south stars of about 25°.

During the summer of 1908 the longitude work involved an unbroken series of observations from the middle of May to the middle of October, as well as some additional observations in November and December; whenever possible at least two sets were observed on each night; the home observations were divided among three observers, two of whom observed usually on alter-

nate nights, the third at less frequent intervals; two field observers worked independently of each other at different points throughout the country.* The clock used in the home observations (Riefler No. 75) had a very steady rate, and it became apparent on inspection of the results for successive nights that the observations were affected by personal equation. This was very clearly seen on plotting the results in a curve, using different colored inks for each observer; it was also quite noticeable that the personal equation of N had suffered a sudden change between July 13 and July 16. To determine the values of the personal equations the summer was broken up into periods during which the curve appeared most regular; then for any one period the mean of the observations on each night was represented by the observation equation.

$$a + b\,t + c\,t^2 + e = \triangle \mathrm{T}.$$

t being the interval from a fixed epoch, a, b and c arbitrary constants, $\triangle$T the observed clock error, and e the personal equation of the observer referred to the standard observer. It will be seen that this amounts to assuming that the clock-rate, during the period considered, varied uniformly with the time; the periods were so chosen, by inspection of the curve, that this condition should be approximately fulfilled; even if this were not the case the deduced values of e would still be trustworthy, provided the work of each observer were distributed fairly uniformly over the whole period. After combining the observation equations and deducing the values of personal equation and of a, b and c for each period, these values were substituted in the observation equations and the residuals formed. As the average of the residuals for the summer was ·022 sec., the largest being ·06 sec., it follows that the observations are fairly well represented by the formula. The values of personal equation for the different periods were then combined, on the assumption that those of S and C S remained constant throughout the season, while that

* The five observers will hereafter be referred to as follows:—J–W. C. Jaques; M–F. A. McDiarmid; N–D. B. Nugent; C S–C. C. Smith; S–R. M. Stewart.

of N (as was evidenced by the clock-curve) suffered a sudden change in the middle of July.

To obtain the personal equations of the two field observers, M and J, some additional observations were made, the field observers occupying a pier immediately south of the one where the home observations were taken. The observations with M extended from September 14 to October 14; those with J, who did not return from the field until later, from November 21 to December 5. During a part of this time the home observers frequently observed together, two at a time, in order to strengthen the determination both of their own personal equations and of those of the field observers. In doing this, one observer would follow the star over a group of contacts at a considerable distance from the centre of the field, the other over a group somewhat closer; after reversal the same series of observations was repeated in the reverse order; thus the observations of each observer were complete in themselves; the groups of contacts made by each observer were interchanged for alternate stars. It was found that for the November and December observations the personal equation of N had again suffered a decided change of over a tenth of a second; those of S and C S, however, appeared to have remained unchanged; consequently in obtaining the personal equation of J only the observations of S and C S were used.

As will appear below, it seemed likely from other evidence that the absolute personal equation of C S was small; for this reason he was chosen as the standard observer.

The values obtained for the five observers are as follows:—

J	·061 sec.
M	·025 sec.
N	−·079 sec. up to July 15; −·14 sec. July 15 to October 15.
C S	·000 sec.
S	·034 sec.

Though perhaps not as accurate as might be desired, the application of these corrections improved the general agreement

of the longitudes derived on different nights, and there is at least no doubt of the real existence of personal differences of about the magnitudes indicated. It follows that it is never safe to assume the absence of personal equation with the transit micrometer, as was the tendency for some time after its introduction ; though some of the differences involved above are small enough to be neglected except in the most refined work, several of them are of quite appreciable magnitude. They are, however, much smaller than the personal equations ordinarily occurring in key observations.

In considering à priori the question of personality with the transit micrometer, it would appear that there are two factors capable of affecting the result. On account of the motion of the star, there may be a tendency always to keep the moveable wire either ahead of or behind the star, irrespective of its apparent direction of motion ; the distance between star and wire, expressed in angular measure, might be expected to be somewhat less for the more slowly moving stars, but this tendency would be, to some extent at least, counterbalanced by the greater value (expressed in time) of any particular angular interval for the latter class of stars ; thus the tendency would be for the record to be made either too soon or too late by a quantity which might be sensibly the same for stars of all declinations ; this is a personal equation of the same kind as the so-called "re-action time" in observations by eye and ear or with the telegraphic key, but it might be expected to be smaller. The second factor is the personal error of bisection, by virtue of which an observer may tend always to set the wire either to the right or left of the centre of the star-image which he attempts to bisect ; this effect would change sign with the direction of apparent motion, and its absolute value would be proportional to the secant of the declination, changing sign at the zenith and at the pole ; it might also be expected to vary with the magnitude. This error is also present in the case of estimation of transits across fixed wires ; there is, however, so far as the variation with magnitude is concerned, the difference that in the latter case the tendency is usually to

estimate the bisection of a bright star sooner than that of a faint one, irrespective of the direction of motion, while in the case of the transit micrometer differences of magnitude will presumably, simply have the tendency to increase or diminish the error of bisection.

Errors of the first class arise from the motion of the star, but are independent of its direction ; those of the second class do not arise from the motion, but (when expressed as corrections to the time of transit) change sign with its apparent direction ; the former will affect the time, but not the azimuth ; the latter both, but more markedly the azimuth.

It had not long ago been noticed by the writer that, for his own observations, it was impossible satisfactorily to combine observations of south stars with those of north stars at both upper and lower culmination ; this for the reason that the stars at upper culminatian, when combined with the south stars, gave values of clock error and azimuth consistently differing from those derived from the stars at lower culmination. This circumstance was inexplicable by supposing that the observations were affected by a systematic error of bisection, and by no other hypothesis except that of systematic catalogue error ; it was found that the observations could be reconciled by supposing that the wire was set always to the left of the star by somewhat over a second of arc.

During the summer of 1908 it was decided to make some special observations to test, qualitatively at least, the validity of this hypothesis. In order to obtain as many independent tests as possible, several methods of observation were devised. The most obvious of all, the observation of transits of zenith stars facing alternately north and south, was impracticable with the telescope used, since the standards interfered with the proper manipulation of the micrometer wheels. The first method used was the measurement of zenith distances ; as the telescope was fitted with an erecting diagonal eye-piece, this was comparatively simple. After setting on a star at some distance from the zenith, preferably a slow-moving north star (the micrometer head hav-

ing been previously turned so that the movable wire was horizontal), the diagonal eye-piece was turned in either direction about 45° from the vertical plane ; on looking into it with the line joining the eyes horizontal, the micrometer wire appeared vertical, the direction of increasing zenith distance being towards the right or left according to the direction in which the eye-piece had been turned. By making a number of settings with eye-piece alternately right and left, the error of bisection was readily found. In this method the question is not complicated by the motion of the star, which appears to move *along* the wire, the motion in any case being very slow if high polars be chosen ; thus the result is practically the simple error of bisection for a stationary object. By combining the results from different stars the variation depending on magnitude may also be faund. The stars principally used were Polaris and λ Ursæ Minoris ; with the latter as many as a hundred settings could easily be made at one culmination. Several other stars of high declination were also used, the total number of bisections made being about 400. Observations of a similar kind on Polaris and λ Ursæ Minoris were also made by C. C. Smith.

The other methods used, which were three in number, all depended on the observation of transits. They were as follows :—

I. Observations of the same star (over different parts of the field) were made with the ordinary diagonal eye-piece (erecting), and also with a simple eye-piece of about the same magnifying power ; as the apparent direction of motion is altered by interchanging the eye-pieces, the difference in times of transit (reduced to the meridian) was taken to be double the error of bisection. In this case the observations are not made under exactly similar conditions ; with the direct eye-piece a movement of the hand-wheels appears, to an observer accustomed to the erecting eye-piece, to move the wire in the wrong direction, and there is no assurance à priori that this will not alter the "lag" effect, if this exists. The definition is also somewhat better with the direct eye-piece, which might tend to diminish the error of bisection in that case ; the result might also be affected by the difference in

the observer's position. On account of the use of the direct eye-piece observations were not possible within about 35° of the zenith ; stars were observed near the equator and near the pole, both above and below. When reduced to equatorial interval it was found that the error of bisection was practically the same for polar and equatorial stars, the difference in times of transit being, as was expected, of opposite sign for north stars at upper culmination. Care was taken to have the magnitudes varied enough to determine the magnitude equation ; the whole number of stars observed was 45.

II. Observations of a few equatorial stars were made in the ordinary way, and also with the diagonal eye-piece turned through 180°, so that the observer faced upwards at an angle in looking into it. As before, the error of bisection was taken to be one half the difference in the reduced times of transit. Theoretically this method is free from objection, as the conditions of observation are the same in both cases ; practically, however, the difficulty of observing with the eye-piece down, without a suitable reclining chair, was found to be a very serious objection ; only twelve stars were observed.

III. As in the case of the zenith-distance observations above, the star was observed with eye-piece both left and right, and also (over another part of the field) in the ordinary way. With eye-piece left the apparent motion of the star was upward, the wire appearing horizontal ; with eye-piece right the motion was downward ; the mean of these two observations was taken to be free from error of bisection ; hence the error for the ordinary observation was derived. The number of stars observed was 43.

In the several methods described above the results are independent of catalogue places, and include both the absolute value of the error of bisection and its variation with magnitude. Computations were also made from the residuals of the southern *Berliner Jahrbuch* stars occurring in the ordinary observations, to determine the magnitude equations in the case of both S and C S; this involves the assumption that the *B. J.* places are free from magnitude equation, which is probably very nearly the case.

The residual of each *B. J.* star in a set was diminished by the mean of all; the same was done with the magnitudes; there results for each star an observation equation of the form $b\ m = v$, m being the magnitude of the star diminished by the mean magnitude for the set, v the residual diminished in the same way, and b the unknown magnitude equation; the reduction to this form enables stars from different sets to be combined indifferently to obtain the value of b. 170 stars were used in deducing the magnitude equation of S, 143 for that of C S.

From the observations by S and C S in October and November, on the nights on which the two observers worked simultaneously with the same instrument, a computation was made of their difference of personal equation and its variation with magnitude, on the supposition that it was wholly due to bisection error. This supposition appeared extremely probable from the fact that of 19 north stars (at upper culmination) and 43 south stars, every one of the north stars gave a negative difference in the sense S − C S, and every one of the south stars a positive difference. The signs of the differences for the north stars having been changed, each star furnished an observation equation of the form $a + b\ m = v \cos \delta$ for the determination of difference of bisection error, a and b being the quantities to be determined, m the magnitude, and v the observed difference. The 62 equations were combined by least squares, and a and b evaluated.

The results of all the observations and computations described above are collected in the subjoined table. In the case of the zenith distances the bisection errors, for the sake of uniformity, have been reduced to their equivalents in time; all the results are expressed in equatorial interval; the bisection error has throughout been considered positive when the wire is set to the apparent left of the star. The inter-agreement of the means is no doubt much closer than might have been expected from the varied nature of the observations and their comparatively limited number. The results, however, point very strongly to the reality of a large bisection error for the observer S, and to its variation with magnitude; the agreement for the two observers points

to the probability that their personal equations arise almost wholly from this cause, For a set observed at the latitude of Ottawa (45° 24′), composed of north stars of magnitude 5·5 at declination 77° and south stars of magnitude 4 at declination 25°, which is about the average composition, the personal equation between S and C S due to the error of bisection, assuming the latter to be ·074 sec. – ·0129 (m – 4), would be ·036 sec. ; the actual value as obtained directly above was ·034 sec. The closeness of this agreement is, however, no doubt partly attributable to chance.

The observations of N in October, on the three nights when he worked simultaneously with S, appear to follow a similar law, the differences being all negative for the north stars, and nearly all positive for the south stars ; for his observations in November and December, however, after the second change in his personal equation, this is not the case. The observations were considered too few to make a definite analysis ; his magnitude equation during the early part of the summer, as deduced from the residuals, was – ·0019 sec. per mngnitude, a practically evanescent quantity.

It may be remarked that transit of stars near the zenith, observed with a broken-type telescope, will be free from error of bisection when the telescope is reversed during the observation of each star. For an ordinary telescope the condition of elimination, so far as the effect on the deduced clock-error is concerned, is that the sines of the mean zenith distances of south and of north stars should be proportional to the errors of bisection corresponding to their respective mean magnitudes, provided that the zenith distances and magnitudes of individual stars do not differ widely from these means. As however, the fulfilment of this condition, even approximately, would be extremely difficult in actual practice, and as the resulting error varies fairly rapidly with changes in the conditions, the only practical remedy would appear to be the measurement by each observer of his bisection error and the correction of each separate observation for it if large. Observations of both Polaris and λ Ursæ Minoris at a

single culmination, by the method outlined above, would be sufficient to determine whether the error and its variation with magnitude were sufficiently large to be taken into account; if so, further observations of the same kind could be made if desired.

In the measurement of azimuth by the transits of close circumpolars, the clock error being supposed known, the error of bisection enters for more than its full value into the deduced azimuth. In this case the error might either be measured directly as above, and a correction applied, or it might be eliminated by observing with eye-piece alternately left and right as described under III. above.

ERRORS OF BISECTION

Method	Observer	Bisection Error	
		s	s
Zenith distance	S	·074	− ·0119 (m−4)•
Transits I.	S	·101	− ·0091 (m−4)
Transits II.	S	·066	·0088 (m−4)
Transits III.	S	·151	·0252 (m−4)
Residuals	S		− ·0118 (m−4)
Zenith distance	C S	·033	± ·0000 (m−4)
Residuals	C S		− ·0038 (m−4)
Direct differences	S − C S	·074	− ·0129 (m−4)
		s	s
Means	S	·098	− ·0134 (m−4)
	C S	·033	− ·0019 (m−4)
	S − C S	·074	− ·0128 (m−4)

DOMINION OBSERVATORY,
OTTAWA, CANADA,
December, 1909.

Halley's Comet as seen on November 11, 1835. Drawn by C. Piazzi Smyth, at the Cape of Good Hope.

HALLEY'S COMET*

By C. A. Chant

THE appearance of a comet in the sky has always aroused interest and sometimes fear. The ordinary heavenly bodies move according to such well-determined laws that the astronomer can tell us precisely where any one of them will be at any specified time centuries hence. But when, without any previous intimation, a comet is announced, the majestic uniformity of the celestial motions seems to be deranged, and it is looked upon as a supernatural visitor. The most wonderful phenomena, simply because they occur regularly about us day after day, are treated with indifference; but the unforeseen and extraordinary always arrest our attention and give rise to fear, never to joy or hope.

The dread of comets, however, is not nearly so prevalent now as in former times. Though we cannot usually predict when a comet shall appear, yet the way in which such bodies move is now well known; and the beginning of our real knowledge of these matters dates from the time of Halley. In ancient astronomy comets had no place. Ptolemy, whose treatise was the standard for fourteen centuries, does not mention them. They

*The Editor has had many requests for articles of an untechnical nature. He would be glad to receive such with a view of inserting them in the Journal. The following paper was printed in the February Number of *The Westminster*, (Toronto, Ont.)

PLATE VII.

PORTRAIT OF HALLEY
(From the frontispiece in Halley's *Astronomical Tables*, 1752).

were thought to be atmospheric meteors or terrestrial exhalations.

Comets vary widely in their appearance. Some of them are magnificent objects with tails stretching in graceful curves across the sky, but many are just faint hazy patches of light, visible only in a telescope. There has not been a conspicuous comet since the year 1882, although since then 135—averaging five a year—have been discovered. Most of these could be seen only with a telescope, though occasionally one has been bright enough to be detected with the naked eye. The brightest of these was discovered on June 10, 1907, by Daniel, of Princeton, N. J. For more than a month it was visible in the eastern sky for an hour or two before sunrise.

But why is Halley's comet so famous, and indeed why is it known by his name at all? Usually the comet bears the name of its discoverer, but such is not the case with this one.

Edmund Halley was born on October 29, 1656, the son of wealthy parents. He early showed exceptional ability, and his father gave him a good education. While a youth he learned to make dials, and he became so thoroughly acquainted with the heavens that it was said that if a star were displaced in the sky he would presently find it out. He was equally distinguished for classical and mathematical ability. At the age of nineteen he entered Queen's College, Oxford, but before this time he had made important observations on the variation of the mariner's compass. While a student he made improvements on the method of determining planetary orbits, and this work impressed on him the necessity of charting the stars in the southern hemisphere. In this project his father supported him, and without waiting to take his degree, he embarked in November, 1676, for St. Helena, where he remained for two years. On his return, the University, at the King's command, conferred on him the degree of M.A.

About fifty years before this (1617-1620), Kepler had published his famous three laws of planetary motion. These laws state that the planets move about the sun in ellipses of which the sun occupies one focus; that the straight line joining the planet

to the sun, called the "radius vector," moves over equal areas in equal times; and lastly, that there is a definite relation between the time in which a planet makes a complete revolution about the sun and its mean distance from the sun. (The square of the time is proportional to the cube of the distance). Kepler deduced these laws from an exhaustive examination of the records of the motions of the planets, and he assigned no physical cause for them.

Hereafter the underlying reason for the three laws was a subject for much research amongst scientific men. Halley pondered upon it but without success. He discussed the matter with Hooke and Wren, two of his distinguished contemporaries, but they could not help him. Then, in August, 1684, he went up to Cambridge to consult Isaac Newton about it, and to his surprise and great delight he learned that the latter had completely solved the problem, and that Kepler's laws were simply deductions from the single principle which we now know as the law of gravition.

Halley learned that Newton had made many mathematical investigations upon the motions of bodies, and recognizing the surpassing value of this work he urged Newton to publish it. But Newton was modest and retiring, and having had some unpleasant experiences with jealous contemporaries, he shrank from further trouble. Halley, however, continued to urge him forward, and at last, after much persuasion, he consented, and presented to the Royal Society the manuscript of that work which is known as the "Principia," the full title being the "Mathematical Principles of Natural Philosophy." This is generally recognized as the greatest contribution to science ever made by anyone. It was ordered to be printed at the cost of the Society, but the funds had all been used up, and so Halley, though now in reduced circumstances, with generous loyalty assumed the entire labor of editing and the cost of printing and publishing the book. But for Halley's unselfish interest the work would have been long postponed; perhaps, indeed, never completed.

In October, 1698, Halley was commissioned by the King to

make extensive observations on terrestrial magnetism. This occupied two years; and then, also by royal command, he made a careful survey of the tides and coasts of the British Channel. After this he made a journey to Dalmatia for the purpose of selecting and fortifying the port of Trieste. On his return he was chosen, in November, 1703, Savilian professor of geometry at Oxford.

In the third book of the "Principia," Newton explained how to use the principles of gravitation to determine the path of

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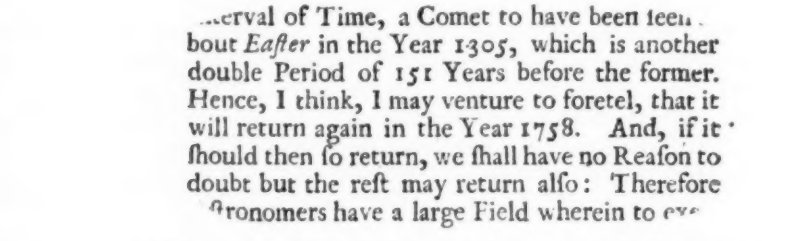
Wherefore (following the Steps of ſo great a Man) I have attempted to bring the ſame Method to arithmetical Calculation; and that with all the Succeſs I cou'd wiſh. For, having collected all the Obſervations of Comets I cou'd, I have fram'd this following Table, the Reſult of a prodigious deal of Calculation: Which, tho' but ſmall in Bulk, will be no unacceptable Preſent to Aſtronomers. For theſe Numbers are capable of repreſenting all that has been yet obſerv'd about the Motion of Comets, by the Help only of the annex'd General Table; in the making of which, I ſpar'd no Labour, that it might come forth perfect, as a Thing conſecrated to Poſterity, and to laſt as long as Aſtronomy it ſelf.

Halley's reference to his "prodigious deal of Calculation."
(Facsimile from Halley's "Synopsis of the Astronomy of Comets" printed in Gregory's *Astronomy*, 1726).

a comet, and he invited astronomers further to apply these principles to various recorded comets. According to the law of gravitation a body revolving about another must move in an ellipse, a hyperbola or a parabola. The method of drawing an ellipse by means of two pins and a string is well known. The farther the pins are apart the more elongated is the ellipse; and the parabola is the curve obtained when we suppose one end of the ellipse

to be removed to an infinite distance. It is the curve described by a body when thrown up in the air. Now comets come to us, sweep about the sun, and then go off again and are lost. There had been a splendid comet in 1680, and having obtained from the astronomers the path it had followed in the sky, Newton showed that its path in space was either a parabola or a very elongated ellipse. He inclined to the latter belief and thought it would return in 575 years. The planets move in ellipses which can hardly be distinguished from circles, but if a comet moves in an ellipse at all it is an extremely elongated one.

As soon as Halley was made Savilian professor he proceeded to work out Newton's views regarding cometary orbits. He gathered together all the records of comets that he could find,

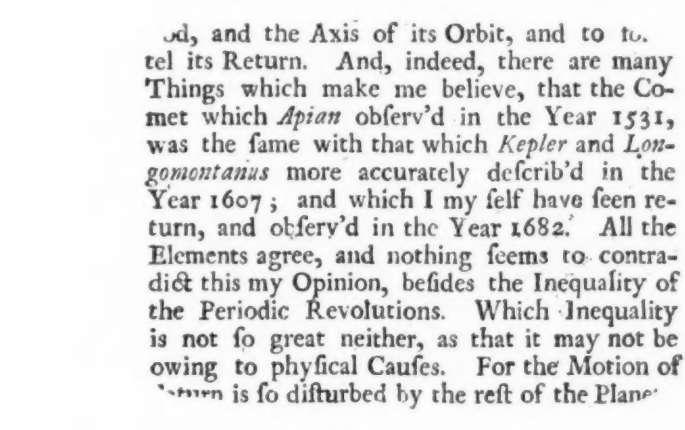

...erval of Time, a Comet to have been feen
bout *Eafter* in the Year 1305, which is another
double Period of 151 Years before the former.
Hence, I think, I may venture to foretel, that it
will return again in the Year 1758. And, if it
ſhould then ſo return, we ſhall have no Reaſon to
doubt but the reſt may return alſo: Therefore
ronomers have a large Field wherein to exe

Halley states his belief that the comets of 1531, 1607 and 1682 were one and the same.

(Facsimile from page 900 of Gregory's *Astronomy*).

and after prodigious labor, published the elements of the orbits of twenty-four, their dates ranging from 1337 to 1698. In describing the orbit of a comet it is necessary to state: (1) When it passes perihelion (*i. e.* when it gets nearest the sun); (2) in what part of the sky perihelion is; (3) where its orbit cuts the ecliptic; (4) the angle its plane makes with the plane of the earth's orbit; (5) its distance from the sun at perihelion; (6) the eccentricity of the orbit; and (7) the direction in which it travels in its path. Even with the improvements made in two centuries the task of computing an orbit is a difficult and laborious one, and Halley deserves infinite credit for his ability and assiduity in accomplishing the immense labor involved.

On examining his list of elements he noticed that the third, the eleventh and the twentieth comets, which appeared in the years 1531, 1607, 1682, respectively, had elements very much alike. Their periods were different, being seventy-six years in one case and seventy-five in the other, but he shrewdly suggested that this difference might be due to the varying attractions of the planets near which the comet had passed. He, therefore, concluded that these three comets were one and the same, and that it revolved in an immense ellipse in a period of about seventy-six years. In his memoir he says: "I think I may venture to fore-



od, and the Axis of its Orbit, and to fo-
tel its Return. And, indeed, there are many
Things which make me believe, that the Co-
met which *Apian* obſerv'd in the Year 1531,
was the ſame with that which *Kepler* and *Lon-*
gomontanus more accurately deſcrib'd in the
Year 1607; and which I my ſelf have ſeen re-
turn, and obſerv'd in the Year 1682. All the
Elements agree, and nothing ſeems to contra-
dict this my Opinion, beſides the Inequality of
the Periodic Revolutions. Which Inequality
is not ſo great neither, as that it may not be
owing to phyſical Cauſes. For the Motion of
Saturn is ſo diſturbed by the reſt of the Plane-

Halley's first prediction of the return of the comet.
(Facsimile from page 900 of Gregory's *Astronomy*).

tell that it will return again in the year 1758. And if it should then so return we shall have no reason to doubt but the rest may return also."

At a later date he became even more convinced of the identity of the three comets, and remarking that the next revolution would be sensibly affected by the planet Jupiter, he thought that the return to perihelion might be delayed till the beginning of 1759. He advised astronomers to watch carefully for its reappearance, and with a patriotic pathos he concludes, "Where-

fore if according to what we have already said it should return again about the year 1758, candid posterity will not refuse to acknowledge that this was first discovered by an Englishman."

Halley died in 1742. As the time drew near for the comet's return great interest was aroused, and much attention was directed to the probable effects of the attractions of Jupiter and Saturn, referred to by Halley. To compute these "perturbations," however, is an extremely difficult and laborious matter; but it was undertaken by Clairaut, an eminent French mathematician. He was assisted by Lalande, the celebrated astronomer, and by Madame Hortense Lepaute, a very capable computer. They worked for six full months, from morning to night, with little intermission even for meals, but at last the work was done. Clairaut announced that the comet would arrive at perihelion within a month of April 13, 1759. In his calculations he had neglected some small quantities which would render the predictions uncertain by a month. All through 1758 professional astronomers were on the watch for the comet, but it was first seen on December 25, by a diligent and keen-eyed amateur named Palitzch, a farmer, living near Dresden, who observed it with a telescope eight feet long. On May 5 the tail was 47 degrees long, and it had been conspicuous for some time previous. The perihelion passage occurred on May 12, just within the limit named by Clairaut.

Halley had passed away, as we have seen, seventeen years before the fulfilment of his prediction, but his name was universally associated with the comet whose return, foretold by him, made a memorable epoch in the history of astronomy.

As the time for its next re-appearance approached, several calculations were made of the time when it should reach perihelion, the most complete being that of Rosenberger, of Halle, who predicted that it would occur on November 11, 1835. As early as December, 1834, eager telescopes were pointed to that quarter of the heavens where the wanderer should appear. The first glimpse was obtained by Father Dumouchel, of the Collegio Romano, at Rome, who succeeded in recognizing the visitor on

...ay, by means of the ſaid Table, compute the ...
...nall for the moſt part find them more agreeable to the Obſervations, than the ſervations are among themſelves.

You ſee therefore an agreement of all the Elements in theſe three, which would be next to a miracle if they were three different Comets; or if it was not the approach of the ſame Comet towards the Sun and Earth, in three different revolutions in an Ellipſis around them. Wherefore if according to what we have already ſaid it ſhould return again about the year 1758, candid poſterity will not refuſe to acknowledge that this was firſt diſcovered by an *Engliſhman*.

...nd this Comet is as it were the *Mercury* ... the Comets, ſurrounding the ...

The famous paragraph in which Halley refers to the periodicity of the comet having been discovered by an Englishman (Facsimile from Halley's *Astronomical Tables*, published in 1752).

August 6, close to the computed place (in the constellation Taurus). It was a faint, misty object, scarcely discernible. As the days went on it increased in brightness, being first seen with the naked eye on September 23, but it was not conspicuous enough to attract general attention until the end of that month. The first appearance of a tail was observed on September 24. In October the comet rapidly increased in brightness, and on the fifteenth of the month the tail reached its maximum length, about 30 degrees. Perihelion was reached on November 16, five

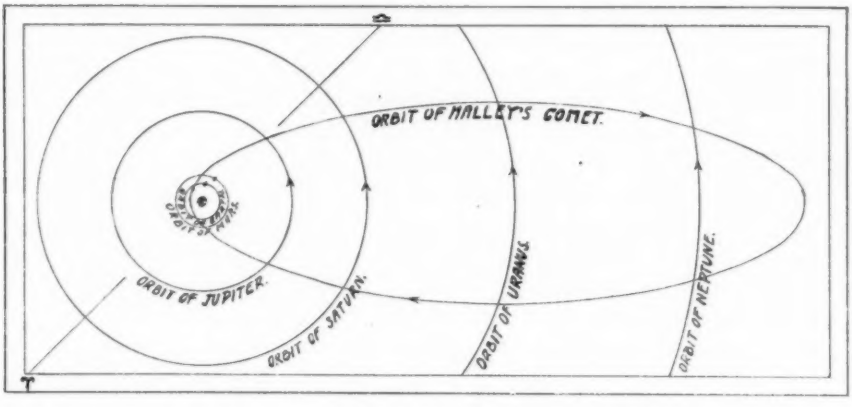


Diagram showing the relative sizes of the orbits of the planets, and of Halley's Comet. The elliptical path of the latter is 3,426 millions of miles long, and 868 millions of miles wide. That point of the orbit nearest the sun is called perihelion; it is 56 millions of miles distant.

days later than the predicted time. From November 22 to December 30 it was hidden in the sun's rays, but on the latter date it was again detected. Observations in the southern hemisphere continued until the middle of May, when the comet was finally lost in the depths of space.

A great welcome has been prepared for the comet on its present re-appearance. Elaborate computations upon its orbit have been made by various astronomers, but especially by Messrs. Cowell and Crommelin, of the Royal Observatory, Greenwich.

The time for passing perihelion was given by them at first as April 8, but a later revision made it about one week later. For months past astronomers were busy photographing the northern edge of the constellation Orion, where the comet should appear, but the first to achieve success was Wolf, of Heidelberg, who announced on September 11 that he had photographed it. When discovered, the comet was distant from the place predicted by only about one-seventh of the moon's diameter! This is a marvellous result, when we consider that the last observation was made seventy-four years ago. On September 16 the comet was

A portion of the tapestry at Bayeux, in Normandy, France. The tapestry is 230 feet long and 18 inches wide and represents the various episodes in the conquest of England by William of Normandy. In the picture Harold on the throne is greatly agitated when the attendant draws his attention to the comet. The courtiers are all terrified at the star — "Isti mirant (ur) stella (m)." Even the birds share the universal dread.

photographed at the Yerkes Observatory, at which time it was equal to that of a star of the sixteenth magnitude. The comet will pass perihelion perhaps eleven days later than the time first set by Cowell and Crommelin.

The date at which the comet will be visible to the naked eye is uncertain, but it may be during February. At that time it

will be seen after sunset in the western sky in the constellation Pisces. Towards the end of March, after passing the sun it will be seen in the morning before sunrise, and it will reach its greatest apparent distance from the sun early in May. Towards the middle of May it will again pass the sun and re-appear in the evening sky. During May the comet should be a prominent object, though it may not be as bright as on previous apparitions, as it is believed that comets continually diminish in brightness until, perhaps, they disintegrate and become swarms of meteors.

The comet will be nearest the earth on May 19, distance about 14,000,000 miles, but at that time it will be so near the sun that it may not be visible. On May 18, the earth will likely pass through the comet's tail (which always points away from the sun), but no harm will result.

At present comets are studied almost exclusively by photography. In this way we obtain a permanent record of minute details which no eye could ever detect.

When the fact had been clearly demonstrated that Halley's comet returned every seventy-five or seventy-six years, efforts were made to identify its previous visits to the sun. Its history has been traced back to 240 B.C. In 1456, it was very bright, and was beheld with awe by the Turks under Mahomet II. and the Papal forces. Its appearance in 1066 is of great interest to us. That the comet was the precursor of the Norman conquest was quite generally accepted. "Nova stella, novus rex!" (A new star, a new king), was a proverb of the time. On the tapestry at Bayeux, which is attributed to Matilda, Queen of William the Conqueror, is a representation of Harold on the throne in great dread of a comet to which his attention has been called by his courtiers. (See illustration). Tennyson in his drama, "Harold," introduces this comet in the first scene:

First Courtier—Lo! there once more—this is the seventh night! Yon grimly-glaring, treble-brandish'd scourge of England!

. . . . . .

Morcar—The people . . . .

. . . . cannot speak—for awe; look to the skies, then to the river, strike their hearts, and hold their babies up to it.

Aldwyth — What thinkest thou this means?

Gamel (a courtier)—War, my lady, war, waste, plague, famine, all malignities.

It is quite probable that Halley's comet was the one described by Josephus as a sword hanging over Jerusalem for one whole year together (A.D. 66), and which marked the beginning of the destruction of the holy city.

Many other historical references have been connected with the comet on its various appearances. Also, since Halley's work upon it must be considered as the beginning of cometary astronomy, we see that the comet has extraordinary interest for all, but especially for the English people.

THE SESIMOGRAPH

By Otto Klotz

A few years ago Professor Wiechert investigated the theory of seismographs, and his results are now applied by most seismologists. The object of the seismograph is to record the movements of the earth or more strictly the movements of the earth particles.

It is obvious that in order to attain that end, we must know the behavior of the instrument when subject to disturbances,—pulsations, in short, the theoretical considerations that come into play for the proper interpretation of the seismogram or record.

Wiechert lays down the fundamental theorem that all seismographs may be treated as mathematical pendulums, of lengths dependent upon the period of the respective seismograph. From this it follows that if T_o = period of the freely oscillating seismograph

$$T_o = 2\ \pi\ \sqrt{\frac{L}{g}}$$

in which L is the length of the simple pendulum. If we imagine the line of the pendulum to be prolonged to a total length J then the extremity will give a magnification V, where

$$V = \frac{J}{L},$$

of the motion of the pendulum.

A pendulum or seismograph once set oscillating would continue to do so indefinitely were there no friction, and with equal amplitudes. The friction in seismographs is generally a small quantity so that the amplitudes do not decrease very rapidly.

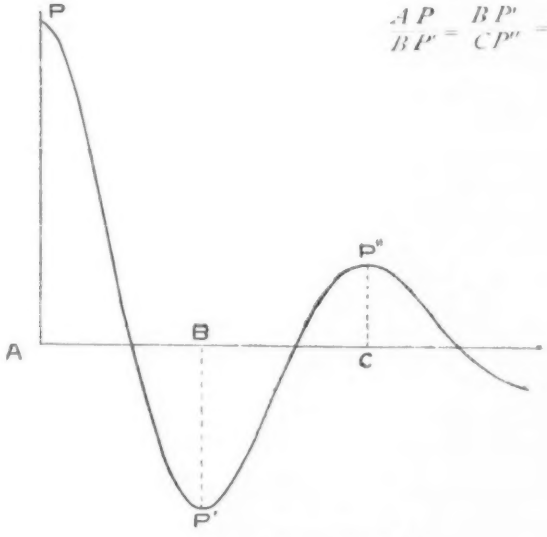
The ideal condition of a seismograph would be when the "bob" or mass were actually a "steady mass," and only the frame supporting the pendulum suffered the displacement produced by the motion of the earth particles. As this ideal condi-

tion cannot be attained we approach it by "damping" the pendulum, that is, the induced oscillations of the horizontal pendulum itself by the pulsations of the earth particles are rapidly reduced in amplitude, so as to mitigate the confusion in the record of the motion of the pendulum itself and the motion of the earth particles. The damping is effected in various ways — by air-chambers, by oil, and by a magnetic field, but mostly the first is applied.

In the accompaning figure the damping effect on the amplitude is shown.

The damping ratio would then be

$$\frac{AP}{BP'} = \frac{BP'}{CP''} = \ldots\ldots = \frac{1}{f}$$



DAMPING CURVE

If T = period of the damped pendulum, we have in time $\frac{T}{2}$ the amplitude decreased by $\frac{1}{f}$ and in time $n\left(\frac{T}{2}\right)$ the amplitude is reduced $\frac{1}{f^n}$. If we designate by τ the time in which the

amplitude is reduced $\left(\frac{1}{e}\right)^{\text{th}}$, where e = base of Napierian logarithms, we have

$$n = \frac{2\tau}{T} \text{ and } \frac{1}{f} = \frac{1}{e^{\frac{T}{2\tau}}} = e^{-\frac{T}{2\tau}}$$

Hence the damping ratio will be $1 : e^{-\frac{T}{2\tau}}$ or $e^{\frac{T}{2\tau}} : 1$.

This ratio is generally written $\epsilon : 1$.

The equation of the damping curve (friction not being considered) is

$$y = c\, e^{-kx} \quad (\pi \operatorname{Cos} \pi x + k \sin \pi x)$$

where $c\pi = d$, when $x = 0$. $\epsilon = e^k$ (e = base Nap. log.)
Hence we may write

$$y = d\, \epsilon^{-x} \left(\operatorname{Cos} \pi x + \frac{\log_e \epsilon}{\pi} \sin \pi x\right)$$

Where $y = 0$, *i. e.*, where the curve cuts the axis of X we have

$$0 = d\, \epsilon^{-x} \left(\operatorname{Cos} \pi x + \frac{\log_e \epsilon}{\pi} \sin \pi x\right)$$

$$\text{or } \operatorname{Cot} \pi x = -\frac{\log_e \epsilon}{\pi}$$

from which the value of x or point of intersection is readily found.

By taking the successive values of x as ·1, ·2, ·3, ... 1·0, where the last represents the foot of the ordinate after one oscillation, or time $\frac{T}{2}$, and substituting them in the general equation, we obtain the corresponding values of y, from which the curve can be plotted for any particular value of ϵ. Further parts of the curve can be plotted with the preceding values of y by simply reducing them respectively by the constant ratio ϵ for the successive oscillation ; by ϵ^2 for the next, and so on.

When there is no damping $\tau = \infty$.

The relation between the damped period T and undamped period T_0 is given by

$$T = \frac{T_0}{\sqrt{1 - \left(\frac{T_0}{2\pi\tau}\right)^2}} \quad \text{or} \quad T_0 = \frac{T}{\sqrt{1 + \left(\frac{T}{2\pi\tau}\right)^2}}$$

The theoretical value of the magnification V of a seismograph may be obtained in various way : — by direct measurement of the displacement of the centre of oscillation of the pendulum with its corresponding displacement of the recording stylus; or, as was done with our Bosch photographic seismograph of 200 grammes, by computing the position of the centre of oscillation from the moments of inertia of the different parts and measuring and comparing this with the distance of the reflecting mirror from the recording surface or photographic sheet. In other cases the compounded system of levers gives the theoretical magnification.

It has been found that the actual magnification with which we have to deal in earthquake records or seismograms is dependent upon the ratio of the period of the pendulum to the period of the oscillating earth-particles, and upon the damping ratio.

Preserving the notation so far adopted, and calling $\mathcal{V}$ the actual magnification, T_0 the period of the earth-particles we have

$$\mathcal{V} = \frac{V}{\sqrt{\left\{1 - \left(\frac{T_e}{T_0}\right)^2\right\}^2 + 4\left(\frac{T_0}{2\pi\tau}\right)^2 \left(\frac{T_e}{T_0}\right)^2}}$$

Remembering that $e^{\frac{T}{2\tau}} = \epsilon$

and $\left(\frac{T_0}{2\pi\tau}\right)^2 = \frac{T^2}{T^2 + (2\pi\tau)^2}$

the above may be written

$$\mathcal{V} = \frac{V}{\sqrt{\left\{1 - \left(\frac{T_e}{T_0}\right)^2\right\}^2 + 4\,\frac{(\text{nat. log})^2}{\pi^2 + (\text{nat log})^2}\left(\frac{T_e}{T_0}\right)^2}}$$

or adapting it to common logarithms

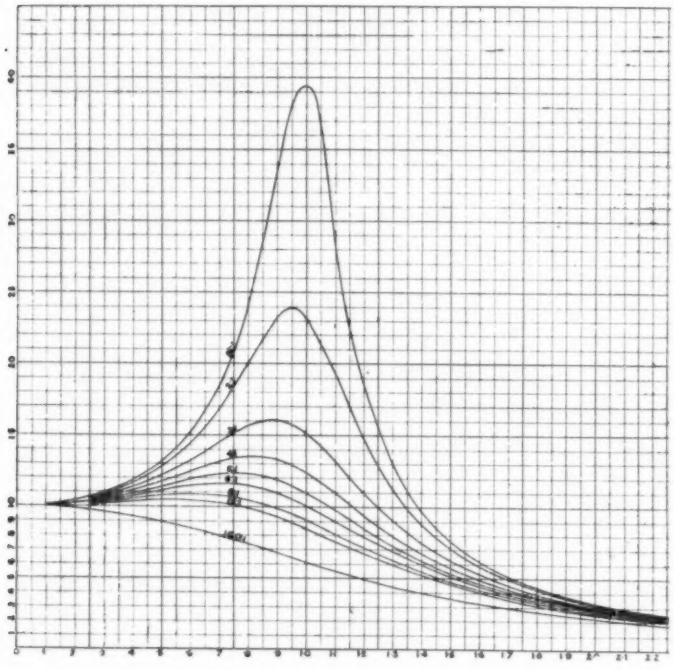
$$\mathcal{V} = \frac{V}{\sqrt{\left\{1 - \left(\frac{T_e}{T_0}\right)^2\right\}^2 + 4\,\frac{\cdot 537\ (\log \epsilon)^2}{1 + \cdot 537\ (\log \epsilon)^2}\left(\frac{T_e}{T_0}\right)^2}}$$

It will be seen that τ' is equal to V when $T_e = 0$, and approaches it when T_e is very small, for all values of ϵ.

Hence at the inset, if sufficiently sharply defined, of the first preliminary tremors we can apply the theoretical magnification.

The best way to get a proper notion of what the expression for τ' means is by a graphic representation.

Values of τ' in terms of τ' have been computed for varying values of the ratio $\frac{T_e}{T_o}$, from 0 to 3 by intervals of ·1, which are laid off on the axis of X. On the axis of Y the ratio $\frac{\tau'}{V}$ is laid off on an arbitrary scale, also at intervals of ·1.



Value of $\frac{T_e}{T_o}$

MAGNIFICATION CURVES

When the ratio $\frac{T_e}{T_o} = 1$, then for $\tau' = 1'$ requires a damping $\epsilon = 6{\cdot}13$.

It will be observed that when $\frac{T_e}{T_o}$ exceeds unity the magnification rapidly decreases.

The value of T_e is, of course, not under our control, but the value of T_o, that of the freely (undamped) pendulum is. The periods of T_e are very variable, in the first place depending upon the phase of the quake to which they belong. In the first preliminary tremors they are always short, from a second upward, while in the principal portion they are always long or relatively long, varying from 6 or 8 seconds to 20 seconds and more. When it is remembered, what a medley of pulsations and waves are sent out by the débâcle of an earthquake it will be apparent that the finding of uniform periods for any length of time, even for a short time, on the seismogram is scarcely to be expected, and in fact is not found except for the long (Rayleigh) waves, which make their appearance after the longitudinal and transverse waves together with their reflections have died out almost completely.

As stated in the beginning, the object or function of the seismograph is to give us a true story of the movements of the earth-particles produced by an earthquake. What interests one, of course, in the first instance is the time element, that is the time or occurrence of the various phases by means of which we determine the distance to the epicentre. This is done wholly empirically. Curves have been constructed on a rectangular system of co-ordinates from the records of various stations of well known (geographically) earthquakes showing the progress of the first preliminary, second preliminary and long waves respectively. So that for any other earthquake if we are able from the seismogram to read the occurrence of the different phases, obtaining thereby the difference of time between the phases, we can readily apply this to the interval between the standard curves above referred to and obtain the distance to the

epicentre with a considerable degree of accuracy, say, within one or two per cent.

As the path of the longitudinal and transverse waves is through the earth, the velocity is a function of the depth ; so that when the velocity of such waves is spoken of, it is simply the quotient of the arcual distance from the epicentre to the station divided by the time interval, and hence is an average velocity for that particular distance.

With a severe earthquake there is never any difficulty in determining the distance to the disturbed area. When the earthquake is very distant, then the horizontal component of the first preliminary becomes very small, with the result, that it probably is not recorded at all ; on the other hand, however, we generally find the long waves to predominate and to be well shown. Beside the first and second preliminary tremors it has been found that frequently with well recorded earthquakes, the seismogram shows reflected waves of the longitudinal and transverse pulsations. It is obvious—taking a once reflected wave of the 1st *P. T.*— that its angle of emergence is decreased and the horizontal component increased. Although some of the energy is lost due to the longer path of this reflected wave, yet the increase in the horizontal component may be sufficient to record it, while the original wave fails to do so. The best records we have here of these reflected waves are of Mexican earthquakes.

For a thorough study of a seismogram it would be desirable to examine it again at a future time, when one has received sufficient reports or data from other stations, by means of which the earthquake can be definitely located and thereby pretty approximate times deduced for the various phases for one's own station, and then comparison made with the waves recorded, which at the time may not have been well recognized as to their relative position.

The problem of determining the direction of the epicentre from the station appears at first sight quite simple. We have two seismographs mounted on a pier, one in the N–S, the other

in the E–W direction, or one seismograph giving the two components.

Let us suppose that the first impulse is sufficiently strong to give a good record at the station. It apparently would follow that $\tan \alpha = \frac{A_E}{A_N}$ where α is the azimuth and A_E, A_N the amplitudes of the east-west, and north-south components. The magnification for the two components is assumed to be the same, which is generally the case or nearly so. Another assumption is made however, about the truth of which we are not assured, and that is, that the direction with which the pulsation arrives lies in the plane of the great circle passing through the hypocentre and station, or whether it has not suffered deflections, especially in the latter part of its course through the various geological formations, where the density varies less uniformly than deeper down in the earth. The deviation from the above plane would probably be confined to the depth of the stratum within which gravitational compensation takes place, being at about 120 kilometres. So far as known to the writer no one has succeeded in definitely deducing the correct azimuth of an epicentre from the reading of a single seismogram, except Prince Galitzin who has recently presented a paper on the subject, given in *Bulletin de l' Academie Imperiale des Sciences de St. Petersburg*, entitled "Zur Frage der Bestimmung des Azimuts des Epizentrums eines Bebens." He puts the question "What is the relation between the measured maximum first offset (amplitude) on the galvanometer-seismogram and the corresponding absolute motion of the earth (surface)?"

He subjects the problem to mathematical analysis, and deduces a formula especially applicable to the conditions of his apparatus, in which the periods of the pendulum are 22ˢ·1 and 23ˢ·4 respectively; and of the galvanometers 23ˢ·7 and 23ˢ·2 correspondingly, while the damping ratio of the former is 1030:1, and of the latter ∞ :1. Galitzin then takes measurements on twelve of his seismograms and computes the azimuth of each epicentre, the geographical co-ordinates of which are known from

other sources, and hence the azimuth of each from Pulkowa. It is found that the two azimuths for each agree pretty well, in a number of cases there is co-incidence to the individual degree, and the greatest difference is 6°. He sums up the results of his investigation :

1. "It is possible from the records of two aperiodic and "highly sensitive pendulums, (application of the gal- "vanometric registration) to deduce with a fair degree "of accuracy the azimuth of the epicentre of an earth- "quake, from the deflections of the pendulums at the be- "ginning of the first preliminary tremors. As the "epicentral distance can be deduced pretty well from "the times *P* and *S* (first and second preliminary "tremors), it follows that the approximate geographi- "cal position of the epicentre can be determined from "the record of a *single* station.
2. "The angle between the plane of oscillation of a particle "on the surface of the earth at the beginning of the "second preliminary tremors, and the principal plane "passing through the epicentre, station and centre of "the earth is in the most cases very small.
3. "The fact that the azimuth of an epicentre can be "determined fairly well from the first preliminary "tremors, may be looked upon as a direct proof that "the elastic oscillations of the first preliminary tremors "really belong to longitudinal waves."

Galitzin draws attention to the occurrence at times of a small "nick" immediately preceding and in the opposite direction to the deflection of the first preliminary tremors. This has been observed too, by the writer and others. The explanation he suggests is the one generally accepted, that it is due to the pier acting momentarily as a pendulum, so that the impulse from the earth to the base of the pier produces apparently a motion in the opposite direction at the top.

In the ultimate analysis of a seismogram we should be able to trace and follow the motions of the earth particles that pro-

duce the seismogram, but this is so involved by the different kinds and periods of waves together with supersposed motion of the pendulum itself, that there is no prospect for a general and complete solution of the interpretation of the seismogram. The few investigators that have attempted the problem have generally confined themselves to the first preliminary tremors of the longitudinal waves.

The recent "thesis" of Hugo Arnold "Die Erdbewegung während des ersten Vorläufers eines Erdbebens" deals with this question. He uses the seismograms of a Wiechert seismograph of 1200 kg., period 12^s to 14^s, magnification 170, and "relaxation time" 5^s, that is the time in which the amplitude of the damped pendulum is reduced $\left(\frac{1}{e}\right)^{th}$. For examination of the seismogram, the first minute = 1 cm. of the quake is enlarged photographically about 10 times and from this the measurements are then made. The registration by the above seismograph is mechanical and involves therefore the friction of the stylus, a serious matter, much more so than the friction of the system of levers and connections is. The determination of the position of the zero line of the pendulum also introduces a difficulty.

Only seismograms giving the two horizontal components were considered. The motion of the particle in space is referred to a system of three rectangular co-ordinates, and a general equation of motion is deduced, covering all the terms that enter into the production of the seismogram. This equation becomes simplified for the horizontal components, which are the ones dealt with.

After all the minute measurements, integration of curves, application and insertion of all terms affecting the record, all of which are carried out with great detail, one is forced to conclude that the results are not satisfactory, and that there are at present no immediate prospects of bettering them.

In other directions the modern sensitive seismograph which is as yet not installed at all seismological stations is giving us valuable information, and that is, with reference to the constitu-

tion of the earth. It is obvious that when a wave is propagated from one part of the earth to another part, the time interval is a function of the density and elasticity of the material along its path. This applies especially to the longitudinal and transverse pulsations whose path lies within the earth. With all the groping of science heretofore about the constitution and condition of the interior of the earth, these pulsations are the first messengers to traverse that interior and through the seismograph write the story of their journey with indelible pencil. With the better class of seismographs and accurate time, the readings can be made to the individual second, (if no microseisms prevail) especially for the inset of the first preliminary tremors of a severe earthquake,— and only such can enter into a discussion of the propagation of the waves through the earth. The problem is an intensely complicated one involving not only the constitution and composition of the material along the path, but also the direction of the impulse to the planes of symmetry of the rocks. This latter consideration will probably be confined more particularly to the first hundred kilometres of the earth.

In 1900 Professor Nagaoka published the results of his investigations on the "Elastic Constants of Rocks and the Velocity of Seismic Waves" in which he gives the values of E, the modulus of elasticity, (Young's) and the modulus of rigidity for rocks ranging from the archæan to the cainozoic period. Then on the assumption that the velocity is proportional to the square root of the elasticity and inversely to the square root of the density, *i.e.*, for longitudinal waves

$$v = \sqrt{\frac{E}{p}}$$

and for transverse waves

$$v_1 = \sqrt{\frac{n}{p}}$$

the corresponding values of v are obtained. He adds "I do not mean to say that the actual velocity of longitudinal waves in various rocks is given by v, but when such values are not obtainable v will probable give a rough estimate." As is to be expected,

the rocks of the older formations show in general a higher velocity than do those of more recent origin.

In the experiments, the maximum velocity was found to be about 7 km. per second, which is a little over half the velocity of the first preliminary tremors, which come *through* the earth. From this it is obvious that for the distance beneath the surface of the earth in which we do find a continuous increase in velocity for those waves, the rate of increase of elasticity must be considerably greater than that of density. What the exact limit of increase of velocity is, is not known. It is supposed to be at about 1500 km. The future study of seismograms will, however, reveal it.

Nagaoka significantly says "The investigation of the seismic waves affords the best means of feeling the pulse of the interior of the earth ; the elastic nature and the density distribution of the constituent rocks, or even the condition of the inaccessible depth will in some future day be brought to light by the patient study of the disturbance, which traverses the strata of heterogeneous structure and appears as tremors or earthquakes on the earth's surface." In connection with the above quotation, it occurs to one that some central bureau should be charged with the collection of reliable seismograms to be put into the hands of a competent geophysicist for investigation. There is now sufficient material available from which important results as to the constitution of the interior of the earth, could be obtained, more than what we now have.

In his inaugural dissertation "Ueber die Elastizität der Erde" (1908) Alfred Brill utilizes the values of Wiechert and Zöppritz for the velocity of the transverse waves, 4·0 km. at the surface to 6·75 km. at a depth of 1500 km., for the evaluation of the mean co-efficient of elasticity for the "mantle" (of a thickness of 1500 km.) and finds it to be $7{\cdot}13 \times 10^{11}$ C. G. S.; this is very nearly that of plate glass ($7{\cdot}24 \times 10^{11}$) given in Adams and Coker's table (*Carnegie Institution Publication*, No. 46). In the above value $7{\cdot}13 \times 10^{11}$ the mean value of v_1 for the mantle is

5·23 km., the mean density 3·2, and the ratio of transverse contraction to longitudinal extension (Poisson's ratio) 0·25.

For the central or remaining inner part of the earth Brill deduces the elasticity co-efficient $14{\cdot}48 \times 10^{11}$ C. G. S. These values from the nature of the data and the manner in which they are utilized can only be approximate values. However, we can confidently look forward to the time when the records made by highly sensitive and efficient seismographs will give us the data whereby the physical constitution of the earth, step by step, from the surface to the centre will be revealed.

At the present moment the reading or interpretation of seismograms from different kinds of seismographs often differs relatively many *minutes*, a condition that must be considered intolerable in any investigation.

About what constitutes the best seismograph for geophysical research, the last word has not yet been spoken.

In the monthly bulletin issued by the Earthquake Station of the Dominion Astronomical Observatory, the Gottingen designations are adopted, as follows :

CHARACTER OF THE EARTHQUAKE

I = noticeable. *II* = conspicuous. *III* = strong.

d = (terræ motus domesticus) = local earthquake (sensible or felt).

v = (terræ motus vicinus) = near earthquake (under 1000 km.)

r = (terræ motus remotus) = distant earthquake (1000 to 5000 km.)

u = (terræ motus ultimus) = very distant earthquake (over 5000 km.

PHASES

P = (undæ primæ) first preliminary tremors.

S = (undæ secundæ) second preliminary tremors.

L = (undæ longæ) long waves (principal portion).

M = (undæ maximæ) greatest motion in principal portion.

C = (coda) = trailers.

F = (finis) = end of visible disturbance.

NATURE OF THE MOTION

i = (impetus) = beginning.

e = (emersio) = appearance.

T = period = twice time of oscillation.

A = amplitude of earth movement, reckoned from zero line.

A_E = E–W component of A

A_N = N–S component of A

} measured in microns (μ)

MEETINGS OF THE SOCIETY

At Toronto

March 1, 1910.—The paper for the evening was given by Mr. L. Gilchrist, M.A., and was on "Light Waves and Their Uses." The properties of light which form the basis for the wave-theory of transmission were considered, and by means of experiments and models its analogy to properties of sound was shown. Stationary waves in gas through which sound is transmitted were compared to the stationary waves in a gelatine film of a photographic plate as obtained by Lippmann and Lehmann. The phenomenon of polarized light was presented to show the reason for believing that the vibrations are transverse.

Various experiments were performed to show interference of light. Newton's rings and the fringes obtained with Michelson's interferometer were projected on the screen. The interference patterns obtained with mica sheets, by Fabry and Perot's plates, and by a Lummer and Gehrcke plate were also exhibited.

Three uses of interference were discussed. (*a*) The measurement af extremely short distances, such as the thickness of the "black spot" in a soap film. (*b*) The determination of the components of a narrow source of light, such as the mercury green and the mercury yellow light. (*c*) The Zeeman effect, *i. e.* the decomposition of a source of light by a magnetic field. The Lummer and Gehrcke plate, the Fabry and Perot interferometer and Michelson echelon spectroscope were adjusted to show these phenomena.

The paper throughout was illustrated with numerous and difficult experiments. A hearty vote of thanks was given Mr. Gilchrist for the great trouble to which he had gone and the

great time he had spent in preparing the paper. After the meeting had adjourned many remained for some time to examine the delicate apparatus and to see the wonderful results obtained with it. C. A. C.

March 15—The paper for the evening was by Mr. E. Jackson, M.A., entitled "With Bernier in the Arctic Circle."

Mr. Jackson, as a member of the staff of the Meteorological Service of Canada, accompanied the expedition for the purpose of making magnetic observations in the far north and in the vicinity of the magnetic pole. The expedition started from Quebec in July, 1907, and reached Etah, Greenland, just after Peary had lest. From August to the same month in the following year the expedition remained at Winter Harbor, Melville Island: and from this station, frequent side trips were made by Mr. Jackson, in which were obtained valuable magnetic data. Of special interest were the splendid series of lantern slides which were thrown on the screen illustrating the character of the land and sea through which the expedition passed. During the summer the snow melted from the high ground of Archaean formation.

March 29—In the Physics Building of the University. The President in the chair.

The paper for the evening was by Dr. W. A. R. Michell, of Toronto, entitled "With Shackleton in Antarctic Seas."

Dr. Michell, as surgeon of the exploring ship "Nimrod," described his experience with the expedition and the nature of the regions passed through in a lucid and entertaining manner, illustrated profusely by lantern slides, for the most part views taken by himself, which were then shown in public for the first time.

On motion of Mr. Paterson and Professor Chant, the lecturer was presented with a hearty vote of thanks.

April 12—A question was asked why Halley's Comet was at first seen in the evening, is now visible in the morning and will be seen later in the evening again, and by request Professor

Chant with the aid of blackboard diagrams explained how these results followed from the relative motions of the earth and the comet.

The paper for the evening was by Professor Chant on "Celestial Motions." It dealt with the simpler phenomena of the motions of the heavenly bodies, and was illustrated by a number of mechanical slides. The paper constituted an introduction to the study of astronomy.

Mr. A. Elvins asked if any physical explanation of Bode's Law was forthcoming. Professor DeLury, the President, gave a lucid account of how some numerical series are discovered. On starting with a given series it is often impossible to deduce at once the law of progression, but by subtracting the successive members one can often determine the law of increase. On writing down the successive mean distances of the planets, the apparent deficiency between the orbits of Mars and Jupiter became evident and also the law according to which the mean distances increased. Mr. Elvins suspected that there might be some physical explanation, — not simply a coincidence of numbers, — and he proposed to give his views at a later meeting.

J. R. C.

At Ottawa

March 10, 1910, 3 p.m.—The following were elected members of the Society :—

R. J. Fraser, Dept. of Marine and Fisheries, Ottawa.

Henry H. Lyman, 74 McTavish St., Montreal.

Geo. H. D. Gibson, Dominion Observatory, Ottawa.

Mr. R. M. Stewart, M.A., then gave a paper on "Flexure in the Axis of a Meridian Circle."

After defining flexure and illustrating its effects according to the distribution of the mass of a body relative to its points of support, Mr. Stewart made a sketch of the meridian circle, pointing out how it was supported and also how its weight was distributed. The axis was practically a loaded beam supported at two points. The total weight was about 800 pounds. If the

flexure due to this weight were uniform, *i. e.* if no point of the axis was weaker than the rest, there would be no error due to the flexure. If, however, one point of the axis were weaker than the rest there would be an error of level ; but as level is measured in this case by a mirror of mercury the error would be corrected for, provided the flexure were constant as the telescope was revolved about its axis.

If the flexure were not constant, as the telescope was revolved about its axis, and if the change of flexure did not occur at the middle of the axis there would be a variable error of collimation, whose value would depend on the differences of rigidity in different positions.

When the Ottawa Meridian Circle arrived from the makers it was found that the large circles bearing the graduations were not parallel to the plane in which the telescope revolves. This affects the "error of run" of the microscopes and consequently it had to be corrected. A means was devised for testing the amount of error, use being made of one of the microscopes. After correcting for the error by taking off the higher spots of the surfaces of contact between the circles and the axis, and after repeated trials it was found that there were residual effects not accounted for. Grouping these for different positions of the telescope it was found that they had a recurring period of 180°. Irregular flexure of the axis was considered to be the explanation.

Mr. Stewart devised a method of measuring the flexure of the axis directly. A mirror was attached to the end of the axis and a microscope with a nadir eye-piece was placed in position before it and adjusted so that the cross hairs coincided in position with their reflection from the mirror. This defined the normal to the mirror and any change in its position as the telescope revolved could be measured by a micrometer.

By taking readings in different positions of the telescope, the mean direction of the prolongation of the axis, and its variations from that mean direction (*i. e.* the differential flexure) could be measured. By comparing this mean direction with the mean direction of the line through the two pivots the whole

flexure was also obtained. The results showed that while the total flexure was practically the same at both ends of the axis, the differential flexure was different; the maximum flexure occurred at both ends of the axis when the telescope was vertical. Hence the axis was least rigid in the plane passing through the tube of the telescope, and the maximum difference of rigidity was apparently at a point which did not coincide with the middle of the axis; thus a variable error of collimation was to be expected. The actual effect of this irregular flexure remained to be measured.

After this Mr. F. A. McDairmid, B.A., gave a paper on "Latitudes."

Mr. McDiarmid first defined geographic, geocentric and astronomical latitude, derived formulæ connecting the first two and showed that the astronomical latitude was generally different from the geographic latitude owing to the local deflection of the plumb line. To illustrate this he gave several points in Western Canada whose geographic latitude had been calculated and compared with the astronomical latitude as observed.

Mr. McDiarmid then outlined the methods of finding the latitude of a place, or in other words finding the altitude of the pole or of the highest point of the equator. The requisite formulæ for each method were derived and the advantages and disadvantages of each method pointed out. That with two transits of a circumpolar star, one above, the other below the pole was suitable for observatories as it was independent of the declination of the star. The observation of the altitude of stars near the meridian gave very accurate results from a comparatively small number of pairs observed, although the observation was a rather difficult one. The observation of a star on the prime vertical also gave the latitude. Talcott's method was discussed at some length and examples given of results. Mr. McDiarmid stated that very little was to be gained by observing the same pair of stars on more than three or four nights, as could be seen by noting the relative weights of the results. In the reduction of stars to apparent places a shortened method had been worked out by Mr. Tobey,

of the Observatory. In this method the right ascensions of the stars of a pair were assumed equal ; also the sum of their declinations was assumed to be equal to twice the latitude. In this way the work was shortened by about half and in addition, by using natural sines, cosines, etc., the arithmometer could be used. The method was always correct within $\frac{1}{10}''$ arc and could be rendered correct to any desired degree by the use of auxiliary tables.

Mr. McDiarmid then discussed the sources of error. The error of bisection amounted to about 0·3″ and the average error of declinations as calculated about 0·16″.

Another method given by W. E. Cooke, of the Perth Observatory, Western Australia was also commented on.

After a discussion of Mr. McDiarmid's paper the meeting adjourned.

March 24, 8 p.m., in Y.M.C.A. Hall.—Mr. J. S. Plaskett, B.A., lectured on the "Determination of the Constitution and Radial Motion of the Stars," this being the second of the series of three lectures on "Astrophysics."

Mr. Plaskett briefly alluded to the first lecture and showed the relation of the present lecture to that on the optics of the telescope and spectroscope. As knowledge increased, the sciences became divided into various sub-divisions. In the case of astronomy we now have five sub-divisions, viz. descriptive, practical, theoretical and mechanical astronomy and astrophysics. After defining the scope of each of the first four Mr. Plaskett stated that the rest of his lecture would be about the facts and methods of the fifth division—astrophysics.

Light tells us the chemical constitution, the atmospheric conditions and the radial motion of stars. The instrument used is the spectroscope. The history of spectrum analysis was then briefly given, from the first spectrum of Newton to the present.

Mr. Plaskett then showed on a translucent screen continuous spectra and pure spectra explaining the cause of the difference and the necessary instrument for producing a pure spectrum. He then gave examples of continuous spectra, emission spectra

and absorption spectra. The continuous spectrum was produced by a glowing hot solid or liquid body; the emission spectrum, characterized by the presence of bright lines or bands, was produced by a glowing gas or vapor; and the absorption spectrum, characterized by the presence of dark lines or bands, was produced by a solid body surrounded by gas or vapor of a lower temperature. Hence the physical condition of a body governs the character of its spectrum, and conversely, knowing the spectrum of a body, we also know something about its physical condition. In the heavens all three kinds of spectra are met with. Some nebulæ give continuous spectra, showing that they are composed of either solid or liquid particles; many stars and comets give emission spectra, showing that they are composed of glowing gas or vapor; while other stars and the sun give absorption spectra showing that they are surrounded by gases of lower temperature than the interior. The arrangement of the lines in a spectrum is an index of the elements contained in the source of light, for each element has a definite arrangement of lines. Hence we can tell what elements are present in the stars, provided the elements are present on the earth to furnish a basis of comparison. Forty elements found on the earth are known to be present in the sun, and probably all our elements are present in the sun, as doubtless the sun and the earth had a common origin. Of the stars about 39 per cent. have spectra unlike that of the sun.

Mr. Plaskett then explained the principle by means of which we can tell the motion of a star in the line of sight. To obtain a quantitative measurement very fine instruments have to be used, and corrections have to be introduced for the earth's velocity. The velocity of a star in the line of sight could be obtained correct to within ⅓ mile per second. It was possible to calculate these velocities for all stars of the fifth magnitude or brighter. Hence we can hope sometime to ascertain the general motion of the stars and of the sun through space.

Some stars have a periodically variable velocity, and Mr. Plaskett explained how this is due to the binary character of such

stars. Between two and three hundred binary stars have been discovered, the proportion to single stars being as one to five. None of these binaries, however, is visible as double, owing to the fact that the companion star may either be dark or too close to the brighter star, or the system may be too distant. The companion star is not always dark as the spectroscope sometimes shows two sources of light.

Observations on a star give us data for plotting its velocity curve from which we get the elements of its orbit and the velocity of the centre of gravity of the system.

C. E.

At Hamilton

February 25.—Mr. Edgar Scholes, 488 Wilson St., Hamilton, was elected a member of the Society.

A paper by Mr. E. W. Maunder, F.R.A.S., Superintendent of the solar work at the Royal Observatory, Greenich, was read by Mr. G. P. Jenkins.

The work of the observatory along this line was described and a number of slides showing the instruments used were shown.

Mr. Maunder pointed out how Greenwich Observatory had to abandon the rule laid down by Flamsteed and his successors that astronomy properly only concerned itself with the motions of the heavenly bodies, and yet how the new astronomy, brought about by the spectroscope, eventually came under this category, inasmuch as motion was studied therewith.

March 11, 1910.—The local president, Mr. G. Parry Jenkins, F.R.A.S., referred to the comets of 1910 and exhibited three photographic slides of Halley's Comet and Comet *a*, taken at the Yerkes Observatory by Professor Barnard.

The paper for the evening was by Mr. G. G. Pursey, of Toronto, on "A Nebular Theory of Creation."

Mr. Pursey, in his introductory remarks, described the subject as being one of bewildering magnitude, taking in the formation and preparation of the world for human habitation, a process requiring time incalculable in duration. Matter had always

existed, though investigation showed that its conditions were an unsolved mystery. All forms of life were unstable, none endured. One great law that pertained to everything in the physical world was that the constituents of the whole universe were similar and that they were controlled by similar laws, though under diverse conditions. All things, even worlds, passed through the various phases of life, birth, growth, decay and dissolution.

In the study of the formation of the world, the first question that presented itself was the query, "What are nebulæ!" The small patches of luminous appearance, yet little density to be seen in the heavens, those of Orion and Andromeda being most easily visible to the naked eye, had given rise to much speculation as to the part they played in the economy of the universe. They had been judged to be either the debris of old worlds or the material for the formation of new ones. In either case they were part of the process, whether ascending or descending. In taking the luminous cloud and attempting to follow it in the process, one found that he felt with Sir John Herschel, that it was impossible to form a conception of the world apart from the Great Infinite. However, in the consideration of the creation, it might help to consider that space was once filled with the nebulæ. Atom joins atom and by mutual molecular attraction, as the masses form, the force of gravitation fills the masses with energy, and consequent heat resulting from the compression. As heat was a source of motion, the agitation in the solidifying mass became intensified. Then at the signal of the Great Builder, it commenced to revolve, and continued to do so until the energy and heat had been dissipated, and the set purpose of the creation accomplished.

The revolving mass caused to separate from its equator the portions which formed the planets. The zodiacal light, which has never been satisfactorily explained, the lecturer stated, in his opinion, was the reflection of the light of the sun from similar bodies, which moved about the sun in swarms, being the meteorites, which occasionally appeared as earthly showers.

Mr. Pursey then considered the cooling of the earth, the

formation of the crust, and the condensation of the water vapor. After this the first flora and fauna appear. These are elementary forms, such as lichens, but in the course of evolution these forms die and produce subsistence for later forms of life. But whence is life? The answer was that life, being spiritual, was beyond explanation.

The president voiced the sentiment of the audience when he expressed his appreciation of the very intelligent and studious paper and the reverent mode in which the subject had been treated.

April 9. — The following were elected members of the Society.

Mr. Joseph Henry Smith, Public School Inspector, 14 Charlton St. W., Hamilton.

Mr. H. M. Watson, 176 Hughson St. S., Hamilton.

Mr. Wm. F. Stuart, Hamilton.

The president exhibited several slides of Comet 1910*a*, and also a photograph of the 8½-inch reflector being installed at Elmwood Observatory by our vice-president, Wm. Bruce.

The subject for the evening was a paper by H. B. Witton, Esq., on "Selenography."

The lecturer divided the subject into two parts, (1) dealing with the motion and position of the moon in the heavens and (2) the observing and mapping of its surfaces.

The labors of Halley and Flamsteed were traced, the eight-and-a-half years of work on the various motions of the moon serving to confirm and establish the Newtonian theory of gravitation.

The Greenwich Observatory was founded in 1675 largely to observe and calculate the angular distance of the moon from the fixed stars to enable mariners to determine the time and hence their longitude, Flamsteed being appointed the first Astronomer Royal at the munificent salary of £100 sterling and having to furnish his own instruments.

Later a reward of £10,000 upwards was offered for a method of determining longitude at sea either by observations or by time-

pieces, the amount of the award to depend upon the accuracy of the method.

John Harrison received the full amount of the prize, viz. £20,000, for his chronometers which, it is claimed, did not vary one minute in ten years.

In an aside the lecturer mentioned, as of great interest to Canadians, that when on a visit to Montreal some years ago he was informed that the firm of Harrison, Ainsworth, had in their safe the original documents pertaining to this transaction with the Government.

Tables are now published three years in advance, giving the moon's angular distance to one second of arc.

As an instance of the accuracy with which latitude and longitude may now be determined the lecturer referred to the breaking and abandoning of the Atlantic cable which was located in a few hours by the steamer sent to repair it.

Referring to mapping the moon's surface the lecturer spoke of a number of early observers who made sketches of it. Hevelius made a map which for 100 years was the best in existence. He not only made his own observations, but also did his own engraving and printing. High praise was given the map made by Beer and Mädler in the years 1834-36 on a scale 38 inches to the moon's diameter. They made innumerable measurements and named many new features, retaining, however, the style of nomenclature adopted by Hevelius. The telescope used by them was a Fraunhofer 8¾-inch refractor. Reference was made to the excellence of this maker's lenses and his secret, so long kept, of breaking and remelting the glass for his lenses till thoroughly homogeneous. Telescopes of to-day were of such power, however, that objects on the moon 40-feet height might be observed.

Other observational work on the moon was referred to, such as Lord Rosse's determination of the probable difference in temperature during the lunar day and night of over 200°C.

At the close of the lecture several slides were shown giving the various phases of the moon, the lecturer pointing out features of interest, such as the spot where slight activity has been

suspected, the starting-point of Beer and Mädler's measurements, the lowest, darkest, brightest spots, etc., together with such well-known features as Tycho, the Alps, Apennines, etc.

T. H. W.

At Peterborough

February 22.—A large number of people gathered to hear a very able address by Prof. L. B. Stewart, of the University of Toronto, who took for his subject, "How Polar Explorers determine their Whereabouts." Prof. Stewart may be claimed to be of Peterborough, as he is a son of Mr. Geo. Stewart, C.E., long a resident of the city, and also a cousin Mr. T. A. S. Hay, C.E., City Engineer.

Dr. Marsh was chairman, in the absence of the president, Mr. Collier. The formal business of the meeting was transacted, and Dr. Marsh gave a talk on Halley's Comet, its position in the heavens and how to locate it.

Prof. Stewart, having been supplied with a blackboard on which to make diagrams, took up his subject. In an explanation, free from technicalities, he defined latitude and longitude. He exhibited the instruments such as the sextant and quadrant and defined their uses, and how observations were taken and verified. The lecture was full of interest, bearing in mind the recent return of the arctic explorers, Peary and Cook, and the controversy to establish the claims that each had reached the Pole.

At the conclusion of the address a vote of thanks was tendered to Professor Stewart.

April 5.—The attendance was good and the meeting proved highly interesting and instructive.

Owing to the fact that the president of the Centre was the lecturer of the evening and the vice-president, Mr. Fiske, was operating the lantern, the secretary carried out the duties of chairman.

Mr. H. B. Collier, the president, gave a most interesting address, taking as his subject "Meteorites." He gave a very

lucid explanation of the probable origin of the strange rocky bodies that find their way to earth from outer space.

At the conclusion of the address a vote of thanks was passed to Chancellor Burwash, of Victoria University, for the use of the meteorite belonging to the college museum which was on exhibition.

D. B. M.

NOTES FROM THE DOMINION OBSERVATORY

Astrophysics

By the kindness of Dr. King a new lens of large angular aperture and wide field has been obtained for supplementary use in photographing Halley's Comet. The Brashear Stellar Doublet has an aperture ratio of f 4·5, but only includes on the plate a little over 10° of the sky. The full length of the tail could not likely be secured as owing to the method of mounting, the head would necessarily be placed at the centre of the plate and only 5° of tail obtained.

The new lens is a Zeiss Tessar of an aperture ratio of f 3·5, consequently 66 per cent. faster than the Brashear. It has a focal length of 12 inches and as it can be used on an 8 x 10 plate it will cover lengthwise of the plate about 45° of the sky. The camera is mounted on the tube of the 15-inch telescope near the objective and as it can be pointed in any desired direction within 30° of the optical axis of the telescope the whole extent of the tail even if 40° long may be secured.

Tests of the new lens by star trails have shown it to give very good definition and to have a very large flat field. It is to be hoped that weather conditions will allow its satisfactory use.

I am glad to be able to say that Prof. Michelson has ruled a new plane grating for use with our solar spectroscope. He speaks very highly of its qualities and we are looking forward to testing it and to its use in conjunction with the coelostat telescope. The original grating gave such poor definition that no satisfactory work could be done with it. The new grating has just arrived and has been mounted in position, but at the time of writing has not been tested.

Since Halley's Comet passed conjunction with the sun the weather has been so unusually cloudy that observations have been secured on two mornings, April 13 and 15, only. On those occasions Mr. Motherwell reports, newspaper stories to the contrary notwithstanding, that it was still far from naked eye visibility. J. S. P.

MERIDIAN WORK

Preparations are in progress for the longitude work of the coming summer. The most important station to be determined is Winnipeg, which will be in turn used as a base station for other points in the west ; several such points were connected with Winnipeg during the summer of 1909. For the Winnipeg work, the exchanges of time signals will be conducted on a direct wire, without the interposition of repeaters, from the Dominion Observatory to the astronomical station at Winnipeg. In such exchanges, the time of transmission of the electro-magnetic impulse along the wire, which is a quite appreciable quantity, is eliminted from the final result by sending signals in both directions. Owing to the nature of the mechanism of the automatic repeater, there is, however, no assurance that the time of transmission of a signal through a set of repeaters will be exactly the same in both directions ; for this reason it is inadvisable to have repeaters in the circuit when determining the longitude of a base station, where a high order of accuracy is required. It may be remarked that it would probably not be feasible to use such a long unbroken circuit except with a copper wire such as that used by the Canadian Pacific Telegraph Company for their transcontinental work.

The observations at Ottawa will be made with the meridian circle, those at Winnipeg with a portable astronomical transit. In the meantime a detailed series of observations is being made to determine the relative personal equations of the observers who will be engaged in the work. The indications at present are that, as in previous years, these will be found not to be negligible. R. M. S.

THE SEISMOGRAPH—BOSCH PHOTOGRAPHIC, 200 GRAMMES

The following earthquakes have been recorded since the last notes were sent :—

1910		N–S Component	E–W Component
February 18		h m s	h m s.
	Waves	5 29 50 G.M.T.	5 29 42 G.M.T.
	End	. . .	5 52
Quake in Crete.			
February 18			
	Waves	7 29·6	7 29
	Max.	. . .	7 43·6
	Long waves	. . .	7 45
	End	. . .	8 00
February 21			
	Waves	3 50 25	3 50 25
	Max.	3 50 40	3 50 52
	End	3 55	3 55
February 28			
	1st P. T.	21 08 43	21 08 43
	2nd P. T.	21 15 28	21 15 28
	P. P.	21 19 12	21 18 41
	Max.	21 27	21 27
	End	22 25	22 25
March 11			
	Long Waves	7 10·4	7 10·5
	Max.	7 13	7 12
	End	7 32	7 27
Quake in California.			
March 25			
	Waves	15 21	. . .
	1st P. T. (?)	15 35 15	15 35 38
	2nd P. T.	15 44 43	15 44 32
	P. P.	15 52 5	15 52 5
	F.	21	16 10

From the data of several European Stations and of Ottawa, the epicentre of the earthquake of January 22, 1910, (near Iceland) has been determined. The geographical co-ordinates of the epicentre thus found are Lat. = 67° 56′ N. Long. = 16° 45′ W.

In the next number will be given in detail how these projections are carried out.

MAGNETIC RESULTS

The following are the results of the magnetic observations taken by Mr. C. A. French along the Lower St. Lawence on the north shore from Quebec to Blanc Sablon at the entrance to the Straits of Belle Isle, a distance of about 750 miles.

Observation for the diurnal variation were taken at each station, the eastern and the western elongations being observed. The declination given is that for the mean magnetic meridian.

MAGNETIC RESULTS

1909

Station	Latitude		Longitude		Date		Declination			Dip		Horizontal Intensity
	°	′	°	′			°	′	W	°	′	(c g s)
Quebec	46	48	71	15	Sept.	9	18	18·8		76	1·0	·14792
St. Joachim	47	03	70	52	"	12	18	10·8		76	11·0	·14562
Les Eboulements	47	27	70	23	"	16	19	30·2		76	33·0	·14108
Murray Bay	47	38	70	09	"	17	20	5·9		76	34·2	·14100
St. Siméon	47	51	69	52	"	24	19	53·9		76	52·1	·13705
Tadousac	48	08	69	43	"	22	20	17·1		77	17·0	·13420
Les Escoumains	48	21	69	33	June	1	22	6·6		76	51·5	·13879
Portneuf	48	36	69	08	"	5	20	47·2		77	28·5	·13137
Cape Colombier	48	51	69	54	"	8	23	44·5		77	21·5	·13340
Bersimis	48	56	68	40	"	10	21	0·0		77	54·0	·12840
Manikuagan	49	11	68	16	"	14	25	18·0		77	30·1	·13124
Godbout	49	19	67	38	"	16	24	30·9		77	37·3	·12978
Pentecôte River	49	47	67	12	"	21	25	51·3		77	40·3	·12920
Seven Islands	50	13	66	25	"	24	27	2·9		77	51·4	·12670
Moisie River	50	12	66	07	"	27	28	20·7		77	51·2	·12745
Pigon	50	16	65	37	"	30	28	44·2		77	3·4	·13365
Chaloupe	50	17	65	10	July	3	30	16·8		77	43·1	·12807
Thunder River	50	16	64	50	"	6	27	52.8		78	5·2	·12263
River St. Jean	50	17	64	24	"	9	27	38·7		77	9·5	·13370
Esquimaux Point	50	15	63	42	"	14	35	24·5		76	36·1	·13850
Piastre Bay	50	17	62	52	"	19	30	12·6		77	0·5	·13355
Natashkwan	50	11	61	56	"	23	29	35·1		76	48·6	·13498
Kegashka	50	11	61	20	"	29	30	17·9		76	43·9	·13482
La Romaine	50	12	60	44	"	31	35	45·4		77	32·2	·12705
Wapitagun	50	13	60	04	Aug.	3	26	10·9		76	7·0	·13208
Harrington Harbor	50	29	59	33	"	6	31	19·2		76	23·9	·13684
Mutton Bay	50	47	59	06	"	14	30	13·5		76	52·0	·13522
St. Augustine	51	10	58	33	"	18	35	17·8		76	28·9	·13536
Rocky Bay	51	19	58	05	"	21	31	16·1		76	34·1	·13359
Salmon Bay	51	25	57	39	"	23	30	37·9		76	29·2	·13449
Blanc Sablon (Greenly Island)	51	23	57	13	"	27	33	29·0		76	0·9	·13962
Ottawa	45	24	75	43	Apr.	22	12	56·2		75	37·8	·15171
Ottawa	45	24	75	43	Oct.	4	13	0·8		75	42·5	·15127

Beside the general results are given the readings for diurnal variation during the great magnetic storm of September 25, 1909. The observer when he began in the morning was, of course, not aware that a magnetic storm was raging, and was for the moment non-plussed at the known reading of his reference object. In a very few minutes the mystery was solved.

ST. SIMEON, QUEBEC.

Long. 69° 52′ W. Lat. 47° 51′ N.

Readings on magnet No. 10, magnetometer No. 1977, during part of magnetic storm of September 25, 1909.

75th M. T.		Decl. W. of N.		75th M. T.		Decl. W. of N.		75th M. T.		Decl. W. of N.	
h	m	°	′	h	m	°	′	h	m	°	′
7	10	30	13·2	9	06	19	19·1	10	35	20	27.1
	13	28	29·1		08		36·5		40	18	27·1
	16	25	26·8		10		33·1		45	19	21·1
	18	24	55·1		15		41·0		50	20	9·1
	20	24	12·8		20		49·1		55	19	40·5
	22	23	43·1		25		24·7	11	00	19	27·1
	24	23	9·3		30		38·7	1	00	20	9·3
	26	22	27·2		35		22·7		05	19	39·3
	28	23	22·4		40		33·0		10	20	35·1
	29	23	27·0		45		32·7		15	20	43 2
	30	23	6·8		50		17·0		20	21	15·1
	30·5	22	52·5		55		37·0		25	21	10·5
	31·0	22	41·1	10	00		46·9		30	20	39·1
7	32·0	21	55·1		05		52·4		35	20	31·0
8	45	19	23·2		10	20	6·4		40	20	32·5
	50		29·1		15	19	50·7		45	21	29·0
	55		28·7		20	20	0·4		50	20	34·4
9	02		34·5		25	20	6·8		55	20	34·7
	04		46·5		30	20	36·5	2	00	10	5·0

Normal Declination 19° 53·9 W. of N.

OTTO KLOTZ.

DOMINION OBSERVATORY,
OTTAWA, CANADA.

NOTES FROM THE METEOROLOGICAL SERVICE

MAGNETIC OBSERVATIONS

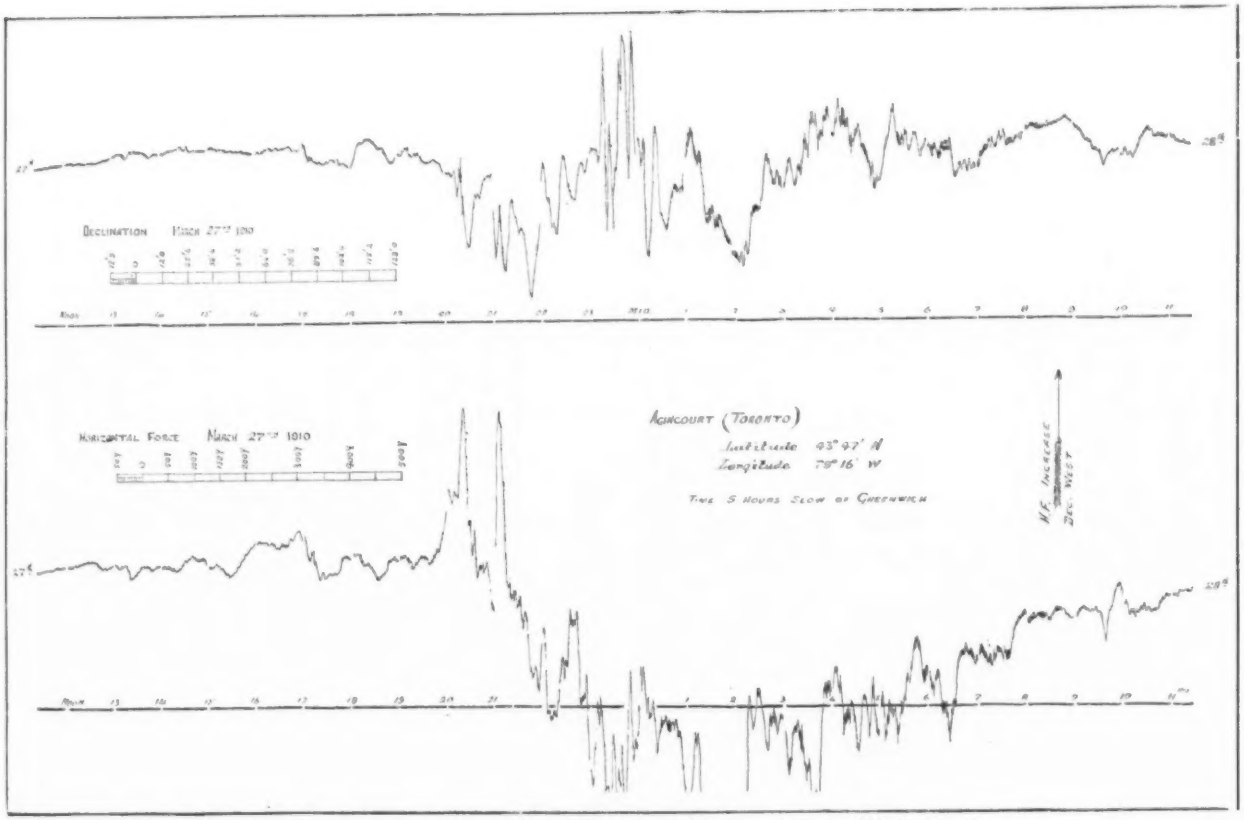
February was free from disturbance of any moment, while on the other hand the magnets were disturbed on almost every day of March and especially so on the 27th and 28th. The commencement of this very pronounced disturbance appears to have been about $17^h\ 0^m\ 17^s$, 75th Meridian time, and the really large movements began about 20^h. The declination reached its greatest easterly elongation about $21^h\ 47^m{\cdot}5$ and its westerly elongation at $23^h\ 54^m{\cdot}1$. The value of H was at its maximum at $20^h\ 23^m$ and at a minimum some time between 23^h of the 27th and 4^h of the 28th, during which period the light was frequently off the recording cylinder.

Declination

1910	Monthly			Amplitudes from Hourly Readings	Mean Amplitude of Daily Extremes
	Mean	Max.	Min.		
	° ′	° ′	° ′	′	′
Feb.	6 01·7	6 18·6	5 47·1	8·0	17·3
March	6 02·5	7 09·9	4 58·9	9·0	25·6

Horizontal Force

Feb.	·162860	·163350	·162095	24γ	47γ
March	·162755	·165860	off paper	27γ	96γ



Record at the Agincourt (Toronto) Magnetic Observatory of the Magnetic Storm of March 27, 1910.

Summary Report of the Weather in Canada

February, 1910

Temperature—The mean temperature of the month was above average in the Maritime Provinces by from 2° to 4°, and either average or below in all other parts of the Dominion. From Quebec westward to the eastern portions of Saskatchewan the negative departures were not very pronounced, but westward of this again, and especially in the northern parts of Alberta and British Columbia, the temperature was very decidedly below average. A marked feature in the West was that the first ten days were exceptionally mild and the Chinook was prevalent, but this was succeeded by a marked change and the balance of the month was characterized by extreme cold which was most severe from the 16th until the 24th. In Ontario and Quebec there were two pronounced cold dips, one early in the month and the other in the last week; while in the Maritime Provinces the only really severe weather occurred between the 23rd and the 26th.

Precipitation—Over the eastern portions of the Dominion, exclusive of Northern and Northwestern Ontario, the precipitation was in excess of the normal amount, but from about Lake Huron westward to the Pacific Coast, there was a very general deficiency. In the Maritime Provinces the greater part occurred in the form of rain, and in Ontario and Quebec, while there were several days of rain, the major part of the moisture fell in numerous light snowfalls. In the Western Provinces there was no rain and the snow was very light, except in Eastern Manitoba, where there were several considerable falls. Heavy snowstorms occurred in British Columbia, and in Vancouver Island the total precipitation was in excess of the average.

March, 1910

Température—The mean temperature of March was above average over all parts of the Dominion from which reports have been received, and in the Western Provinces and Northwestern

Temperatures for February, and March

Station	February		March	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	5	-54		
British Columbia				
Atlin	31	-36		
Agassiz	53	10		
Burkerville	33	-25	54	10
Kamloops	43	-9	70	27
New Westminster	49	-9	65	29
Port Simpson	45	8	54	26
Vancouver	48	13		
Victoria	49	19	64	31
Western Provinces				
Battleford	33	-40	73	-18
Calgary	49	-32	67	10
Carman				
Edmonton	43	-39	68	-21
Medicine Hat	45	-30	76	10
Minnedosa	30	-39	76	-3
Moosejaw	39	-26	78	-5
Oak Bank	36	-37	69	4
Portage la Prairie	34	-29	70	-5
Prince Albert	37	-43	63	-4
Qu'Appelle	37	-42	76	-4
Regina	35	-37		
Swift Current	40	-27	72	-0
Winnipeg	35	-34	73	-4
Ontario				
Agincourt	40	-16	73	10
Aurora	41	-21	73	6
Bancroft	42	-35	70	-6
Barrie				
Beatrice	37	-24	70	-4
Birnam	40	-15	76	15
Bloomfield	38	-16	66	5
Brantford	42	-14	77	14
Bruce Mines	37	-25	65	-5
Chatham	42	-1	80	16
Clinton	37	-22	74	7
Cottam	44	-5	80	14
Cockburn Island	33	-20	67	-6
East Toronto	50	-14	77	10
Gravenhurst	38	-33	70	-7
Guelph	40	-14	75	10
Haliburton	37	-32	65	-8
Hamilton	42	-7	76	15
Huntsville	38	-30	70	-2
Kenora	34	-33	70	0
Kinmount	37	-40	69	-11
Kingston	41	-16	59	7
Lakefield	40	-23	72	4
London	41	-16	79	14
Lucknow	39	-11	73	1
Madoc	40	-24	72	5
Meaford	40	-8	74	8
Midland	50	-17	75	5
North Gower	69	-18	72	6
Otonabee	45	-14	69	7
Ottawa	44	-18	71	-3
Owen Sound	41	-14	77	10
Paris	41	-17	75	13
Parry Sound	37	-24	70	-1
Peterboro'	40	-36	71	4
Point Clark				
Port Arthur	34	-27	65	1
Port Burwell	39	-14	64	14
Port Dover	41	-28	69	14
Port Hope	39	-15		
Port Stanley	40	-15	59	14
Ronville	38	-34	64	-8
Sarnia	40	-10		
Southampton	41	-9	75	6
Stonecliffe	48	-29	73	-15
Stony Creek	43	-9	76	12
Stratford	48	-19	75	8
Toronto	43	-10	75	12
Uxbridge	42	-20	72	6
Wallaceburg	40	-4	76	17
Welland	42	-13	73	9
White River	32	-45	60	-30
Quebec				
Brome	39	-25	62	-9
Father Point	38	-12	42	-3
Montreal	40	-16	64	1
Quebec	41	-13	48	7
Sherbrooke	43	-22	61	-6
Maritime Provinces				
Charlottetown	44	-16	45	-1
Chatham	43	-21	46	2
Dalhousie	43	-20	51	0
Fredericton	43	-25	54	0
Halifax	45	3	59	10
Moncton	45	-19	50	8
St. John	48	-7	47	7
St. Stephen	45	-26	72	6
Summerside				
Sussex	45	-24	49	10
Sydney	45	-8	51	10
Yarmouth	45	6	55	18

Ontario to an extent greater than in any March since 1878, in which year the Winnipeg records show the winter and spring to have been extremely mild. In Ontario, east of Lake Huron, the mean was higher at most points than in any March for which records exist excepting in 1903, when the temperature was slightly higher. Eastward of Ontario a positive departure from average of 8° at Montreal diminished to 4° in Western Brunswick and about 2° in Cape Breton. In the Rocky and Selkirk Mountains, also in the interior plateaus, the excess above average was also most exceptional, but on the lower levels, and along the coast, was somewhat less, amounting to but 2° or 3°. Previous records of high temperatures in March seem to have been broken very generally in the Western Provinces and Ontario. At Toronto the reading 75° on the 28th was the highest March temperature since the establishment of the Observatory in 1840.

Precipitation—The total precipitation recorded in Canada during March was very generally much less than the average, the only districts which recorded an amount in excess of the average were Western Alberta, Eastern Saskatchewan, Manitoba and, locally, the Rainy River district of Ontario. The deficiency was very marked in Ontario and Saskatchewan.

At the close of the month the ground was bare of snow except in Quebec and Northern New Brunswick, where there was a depth of from 2 to 20 inches.

Earthquake Records by Milne's Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1910	P.T Comm h	P.T Comm m	L.W. Comm. h	L.W. Comm. m	Max. h	Max. m	End. h	End. m	Max. Amp. mm.	Durat. h	Durat. m	Remarks
892	Feb. 4	14	30·0					?		0·05	?		
893	" 4	15	08·5					16	24.0	0·4	1	15·5?	Prolonged.
894	" 4	18	41·0					19	30·0?	0·1	0	49·0?	
895	" 12	17	59·5?					18	7·0	0·1	0	7·5	
896	" 12	18	32·0					19	22·2	0·3	0	50·2	
897	" 13	11	23·5					11	37·5	0·1	0	14·0	Doubtful as to being seismic
898	" 18	7	38·0					16	41·0	0·1	0	3·0	
899	" 19	23	25·0?					23	29·0	0·05	0	4·0	Doubtful as to being seismic
900	" 21	16	0·0?					16	4·0	0·05	0	4·0	
901	" 28	21	15·0	V_1 21 19·0 V_2 21 25·2 B 21 29·0		21	31·0	22	20·0?	2·0	1	5·0	Well defined
902	Mar. 10	0	27·5					0	56·0	0·2	0	28·5	
903	" 25	15	45·5					16	3·5	0·2	0	18·0	Thickenings
904	" 30	17	17·0?	Lost. Att'g		Lost		19	45·0	Lost	2	28·0	Portions lost. Attending instrument
905	" 31	18	49·5?		[inst.			19?	38·0	0·1	0	48·5	

Period 14·8 seconds. 1 mm. = 0″·64

VICTORIA, B. C.

E. B. Reed, Superintendent.

No.	Date 1909	P.T. Comm. h	P.T. Comm. m	L.W. Comm. h	L.W. Comm. m	Max. h	Max. m	End h	End m	Max. Amp. mm.	Durat. h	Durat. m	Remarks
919	Feb. 4	14	25·0					14	34·0	0·2	0	9·0	
920	" 4	14	53·0					16	20·0	0·2	1	27·0	Extended small thickenings
921	" 4	18	2 5					18	57·5	0·1	0	55·0	Doubtful as to being seismic
922	" 11	16	33·0					17	1·0	0·3	0	28·0	
923	" 12	18	29·7					19	31·0?	0·3	1	1·3	Slight tremors
924	" 18	7	49·0					7	55·0	0·4	0	6·0	Began gradually. Max. near beginning
925	" 19	23	24·0					23	26·0	0·2	0	2·0	
926	" 21	3	40·0					3	45·0	0·1	0	5·0	
927	" 21	16	44·0					16	47·5	0·2	0	3·5	
928	" 28	21	5·0	21	12·3	21	14·5	22	22·5	9·1	1	17·5	Large
929	Mar. 11	6	59·0					7	7·0	0·4	0	8·0	Gradual swelling. San Francisco
930	" 19	0	13·8	0	15·3	0	17·0	0	25·5	2·6	0	11·7	
931	" 25	15	48·1?					15	56·0?	0·1	0	7·9	
932	" 25	16	10·0?					16	41·0?	0·3	0	31·0	
933	" 30	17	17·2					19	2·0	0·4	1	44·8	
934	" 31	19	33·0?					19	50·0?	0·1	0	17·0	Time marks off the paper. Blasting rock in vicinity of instrument for G.T.P. dock.

Period 15 seconds. 1 mm. = 0″·76.

J. V.

ASTRONOMICAL NOTES

THE SPECTRUM OF COMET 1908*c* (MOREHOUSE). *H. Rosenberg*.—The photographs of the spectrum were obtained with an ultra-violet prismatic camera by Zeiss, and a small and fast hand-camera by Goerz, a replica grating by Thorp being placed in front of the objective. In the table of wave-lengths given the author would identify the 1st, 3rd, and 4th cyanogen bands, while there is not the faintest trace of the 2nd band. The 2nd, 3rd, and 4th carbon bands are also present. The results of the measurements in general agree well with those of other observers. The paper contains also a discussion of spectro-photometric results obtained by measuring the relative distribution of intensity in the spectra of the comet and those of a comparison star. The star chosen was α Lyræ. The comet is much bluer than the hottest white stars. This blueness may be due to the reflection of sunlight by the faintest particles of the cometary material, and the continuous spectrum is produced by a cosmical dust-cloud, in which the diameter of the separate particles may be regarded as something of the order of the magnitude of the wave-lengths. With this assumption an approximate value of the mass of the comet can be derived, if the ratio of the surface brightness of the continuous spectrum of the comet to that of the sun be found. An interesting discussion follows, whence the comet's head having on the measured plates been 5·8 times the earth's diameter, if an albedo 1 be assumed, the mass of the comet, the specific gravity also being assumed as 1, will be $5{\cdot}8 \times 10^{-10}$ that of the earth. For a dark surface, of albedo 0·1,

this value would be increased 10 times. Even if these results are only approximate, the method indicated in the paper shows that valuable results may be expected from photometric evaluation of the plates of the spectrum. On establishing the constants, it is sufficient to photograph a bright star, with measurably altered aperture of the objective, and equal exposure time on the same plate as the comet, or to introduce a change in the exposure time for constant objective aperture as a factor of measurement.—(*Astrophysical Journal*, No. 4.)

THE ORIGIN OF THE SOLAR SYSTEM.—Prof. See's theory of the evolution of the solar system has been criticised by Dr. Fr. Nölke. His main argument is, perhaps, best illustrated by reference to the orbits of seven of the satellites of Saturn. The revolution of these is in the direction in which the planet rotates, and the poles of the revolution axis are all situated within a short distance from the pole of the rotation axis, so that all the revolution and rotation appear to constitute a single system.

If the poles of these revolutions were distributed all over the sky, there would be no objection to Prof. See's theory that these satellites are captured bodies; but, having regard to the actual condition of the system, Laplace's theory furnishes a more simple and natural explanation of it.

Dr. Nölke agrees with Prof. See that the roundness of the orbits is evidence that the motion has been modified by an influence such as would be exercised by a resisting medium.—*Journal British Astronomical Association*, No. 5.

ONE of the most important programs in connection with the astronomy of precision of the southern hemisphere is that inaugurated last year under the auspices of the Carnegie Institution of Washington. It has for its object the measurement of the accurate positions of about twenty-five thousand stars in the southern skies in accordance with the system of Professor Boss, of Dudley Observatory. The instrument employed is the meridian circle of the Dudley Observatory, which has been used in the past for exactly similar work in the northern skies. The

constants, graduation errors, etc., of this instrument have been so thoroughly investigated that doubtless no more efficient instrument exists to-day for this class of work. By the use of the same instrument, the same system of reductions, and to a certain extent even the same observers, it seems probable that the results of this program will afford us a far more exact binding together of the northern and southern skies in one homogeneous system than we possess to-day. The site has been selected at San Luis in the Argentine Republic. Professor Tucker, of the Lick Observatory, is in charge of the Carnegie Observatory at San Luis, and recent advices state that the site seems to be a very favorable one for this class of work ; it is hoped that the number of clear nights will average two hundred per year. The project involves about three years' work, and about seven observers and assistants are employed. Observations will be made throughout every clear night, "from sun to sun," with supplementary observations by day, and at this time the work of the observatory is doubtless in full swing.—*Publications of the Astronomical Society of the Pacific*, No. 129.

THE library of the late Professor Newcomb has been purchased by Mr. John Claflin for the College of the City of New York.

THE University of Oxford has announced that the degree of D.Sc. *honoris causa* will be conferred on Messrs. Cowell and Crommelin for their researches on Halley's Comet.—*The Observatory*, No. 420.

TOTAL ECLIPSE OF THE SUN MAY 8.—This will be visible as a partial eclipse in Australia and the islands in that vicinity. The path of totality starts in the Antarctic Ocean and curves around south of Australia touching land only on the southern half of the island of Tasmania. The eclipse begins May 8, $15^h\ 38^m{\cdot}4$ and ends May 8, $19^h\ 46^m{\cdot}4$ Greenwich mean time.—*Popular Astronomy*, 1910, No. 4.

TOTAL ECLIPSE OF THE MOON, MAY 23.—This will be visible throughout North and South America excepting in Alaska.

The beginning will be visible also in Africa and the southwestern part of Europe. The Moon touches the penumbra of the earth's shadow first at $14^h\ 32^m{\cdot}5$ and enters the umbra at $15^h\ 46^m{\cdot}4$. Total eclipse begins at $17^h\ 09^m{\cdot}0$ and ends at $17^h\ 59^m{\cdot}6$. The moon leaves the shadow at $19^h\ 22^m{\cdot}3$ and the penumbra at $20^h\ 36^m{\cdot}2$ Greenwich mean time. The moon passes through the southern part of the earth's shadow, being darkened first at a point 84° around toward the east from the north point and losing the shadow finally at 49° to the west from the north point of the disk.—*Popular Astronomy*, 1910, No. 4.

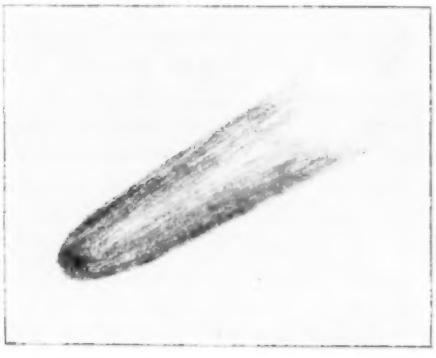
WATER VAPOR ON MARS.—"The observations of Director Campbell on the spectrum of Mars were entirely conclusive in showing that water vapor, if present at all in the atmosphere of Mars, is in less quantity than is contained in the extremely rare and dry part of the earth's atmosphere which is above Mount Whitney. In fact, no evidence at all of water vapor on Mars was detected by Campbell."

"Unfortunately, both Director Campbell and myself were on Mount Whitney during unusually unfavorable weather, for the whole southwest, including northern Mexico, was just at that time visited by floods of rain and cloudy weather. Such a condition would not probably be met with at that season one year in ten," recently writes, C. G. Abbott, who was a member of the observing party.

To this Professor Lowell, in Supplement to *Bulletin* No. 43, Lowell Observatory, replies :—"This admission speaks for itself. The excessive moisture must have pervaded the air generally to the masking of moisture on Mars. Even ordinarily summer is the most unfavorable time for getting any results, because the earth's moisture is then at a maximum."

A. FOWLER, in *Monthly Notices*, R.A.S.C., Vol. LXX., page 182, thus sums up recent attempts in the laboratory, on "Terrestrial Reproduction of the Spectra of Comets" :—"The outcome of the experiments so far carried out is to indicate that the spectra of the tails of Daniel's and Morehouse's Comets were

chiefly derived from some compound of carbon, under conditions which have only been reproduced in the terrestrial gases when at pressure of about one hundredth of a millimetre or less. The difficulties experienced in attempting to determine the precise origin of the spectra given by carbon compounds, even in more familiar circumstances, are so great that the Swan, or candle-flame spectrum, is variously attributed to carbon, hydrocarbon, and carbon monoxide by different authorities. Further work is, therefore, necessary; but it may be remarked that the circumstances under which the new carbon spectrum has been produced are in excellent agreement with the generally accepted views as to the physical conditions which prevail in the tails of comets."



HALLEY'S COMET
AS SEEN FROM TORONTO, APRIL 27TH, 1910
Drawn by Professor C. A. Chant.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

Queries

1. What is meant by "Preliminary Tremors" and "Long Waves" in the notes on earthquakes?

2. What is the speed with which earthquake shocks are transmitted from one part of the earth to another?—Amateur.

Answers

Three distinct kinds of waves are recognized in earthquakes:

The first preliminary tremors;

the second preliminary tremors;

and the long waves; and they are in this order of arrival.

The first are longitudinal waves, like those of sound and travel *through* the earth, but not along a chord; the second are transverse waves, like those of light and also pass *through* the earth; while the third or long waves travel *on the surface*. The velocity of the first is the greatest, and of the third the least. The former increases with the depth, that is the velocity, for instance, for the San Francisco quake was at Ottawa less than for Messina where the path of propagation lay deeper in the earth than for the California disturbance.

The maximum velocity for the 1st P. T. is about 13 km. per second, and the velocity for the long waves is about one quarter thereof, say 3·3 km. per second.

O. K.

Halley's Comet in 1835

The following are notes made of Halley's Comet at the time of its appearance in 1835:—

At last it came, the much talked-of, and long looked-for comet. Papers upon papers appeared before its appearance, and

computations had been made to the greatest degree of minuteness. I myself bought four of these publications. One observed, one looked, as much as the powers of the eye could give. One was told: to-night it must be visible, it has approached us another few million miles, near such and such a star it will be found according to the astronomers; but for all it could not be seen with the naked eye. Of course by means of good telescopes it had been seen for some time, although very faint. The appointed time (5 October, 1835) came, when it was to be near the earth, but no comet was to be seen, and many gave up the hope of seeing it. There then appeared in the newspapers an article by Captain Boguslawsky, of Breslau, wherein the 12 October was given as the time of nearest approach to the earth. (This Captain had already in 1834 published the computations for this comet, but it appeared that they were being crowded out by other computations whose author's believed that they had obtained the only correct results). It was soon shown that Boguslawsky was right in every particular.

At last on 11 October the comet was visible to the naked eye, and as predicted by Boguslawsky near the star Dubhe, the hind wheel of King Charles' Wain (Great Bear). It was finest on October 13, the tail was very long, although faint. It was regretted that this time it reached its nearest distance to the earth before perihelion, for as a rule, as is well known, the tail attains its greatest brilliancy on the return passage from the sun. According to Boguslawsky's computations the comet was to take quite a different path among the stars than predicted by the other astronomers, and he was right. It was still visible on the 17 and 18 October. The nucleus was still bright but the tail scarcely visible. The following nights it was no longer visible to the naked eye, which was due in part to the increasing light of the moon, also to cloudy sky.

EPHEMERIS OF HALLEY'S COMET

In the November-December issue of the JOURNAL was a map showing the path of Halley's Comet amongst the stars. As

stated in the accompanying note, it was drawn from Cowell and Crommelin's search-ephemeris. As this was slightly in error, corrections to the map must be made, and the following table gives the positions calculated on the assumption that the comet will reach perihelion on April 19·65. The table (excepting the third, fourth and sixth columns) is due to Dr. D. Smart and was published in the *Observatory* for November last. In the fourth column is given the distance in hours and minutes of the comet east or west of the sun, and in the last column is given its distance from the earth in millions of miles.

		Right Ascension						Comet E. or W. of Sun			North Declination				△
		Comet			Sun						Comet			Sun	
		h	m	s	h	m		h	m		°	′		°	′	
April	4	0	5	38	0	51		0	45	E.	8	1		5	28	152·2
	8	0	1	43	1	6		1	4		7	58		6	59	144·2
	12	23	57	58	1	20		1	22		7	53		8	28	134·8
	16	23	54	24	1	35		1	41		7	49		9	54	124·1
	20	23	51	44	1	50		1	58		7	46		11	19	111·9
	24	23	50	20	2	5		2	15		7	47		12	40	98·9
	28	23	50	53	2	20		2	29		7	56		13	58	84·9
May	2	23	54	32	2	35		2	40		8	18		15	12	70·4
	6	0	3	6	2	50		2	47		9	5		16	22	55·7
	10	0	21	35	3	6		2	44		10	35		17	28	40·9
	11	0	29	39	3	10		2	40		11	2		17	43	37·4
	12	0	38	32	3	14		2	35		11	41		17	59	33·8
	13	0	50	12	3	18		2	28		12	29		18	14	30·3
	14	1	5	47	3	22		2	16		13	27		18	29	26·9
	15	1	24	47	3	26		2	1		14	36		18	43	23·8
	16	1	49	52	3	29		1	39		15	59		18	58	20·8
	17	2	23	4	3	33		1	10		17	29		19	12	18·3
	18	3	7	19	3	37		0	30	E.	18	51		19	25	16·1
	19	4	3	11	3	41		0	22	W.	19	43		19	38	14·7
	20	5	3	23	3	45		1	18		19	8		19	51	14·3
	21	6	9	54	3	49		2	21		17	40		20	4	14·7
	22	7	3	4	3	53		3	10		15	14		20	16	16·1
	23	7	44	48	3	57		3	48		12	40		20	28	18·2
	24	8	18	20	4	1		4	17		10	24		20	39	20·7
	25	8	40	7	4	5		4	35		8	31		20	51	23·6
	26	8	58	52	4	9		4	50		6	59		21	1	26·8
	27	9	13	8	4	13		5	0		5	45		21	12	30·2
	28	9	24	36	4	18		5	7		4	45		21	22	33·6
	29	9	33	48	4	22		5	12		3	50		21	32	37·3
	30	9	41	23	4	26		5	15	W.	3	15		21	41	40·6

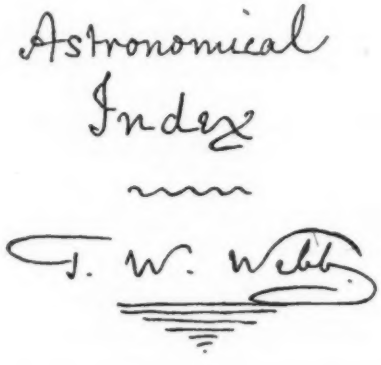
AN INTERESTING BOOK

The library of the Society has received an interesting accession, namely a manuscript Note Book of the late Prebendary

Webb, the author of the well-known work "Celestial Objects for Common Telescopes." It was presented by Mr. G. Parry Jenkins, the President of the Hamilton Centre of the Society, who writes :—

"Webb was at one time Prebendary of Hereford Cathedral, and I lived for over ten years in the City of Hereford. I got possession of the Note Book in 1889 when I was there, and have treasured it ever since. I now wish to denote it to the Library of the R.A.S.C. in Toronto, where it will, I know, be well looked after for the sake of the one man who probably did more than any one else in his day to popularize astronomy. It was Webb too that helped and encouraged G. H. With to make his silver-on-glass specula, which became famous all over the world. I also had the pleasure (as he lived in Hereford too) of knowing With personally, and anybody who knew him—he was a school-master there twenty-five years ago—could not help but love him. Webb and With were bosom friends. I used an 8½-inch With mirror for many years."

The book is bound in leather of convenient size for the pocket, and was begun in 1855. It is a model of neatness and care. Herewith facsimile reproductions of the title-page and a portion of the first page of entries is given—



Rees's Cyclopædia - art. COMET.
Seneca recommended formation of Catalogue.
Bernoulli & Des Cartes, nonsense.
Chief phænomena of Comets.
Hevel, curious account of 1661: - for nuclei, read envelopes?
Proof of 1664 by day, on in very strong twilight.
Newton's theory, of tails ascending in warmed æther.
——— ——— lost & dissipated.
——— spirit of our air may be from comets.
——— may fall into ☉ or ✳✳. (Milne, 180.)
Kepler, tails by impulsion of light.
Marian, from ☉ atmosph: - zod. light - aur. bor (so Euler)
Hamilton, electric light.
Hevel, shadow on tail, 1683.
Halley's possible damage. -
Whiston's deluge v conflagration.
G.S. Dörfell's parabola (a minister in Saxony)
Newton demonstrated return - then Halley.
Halley saw there wd be perturbations.
Cole's idea of comets passing from system to system.

C. A. C.

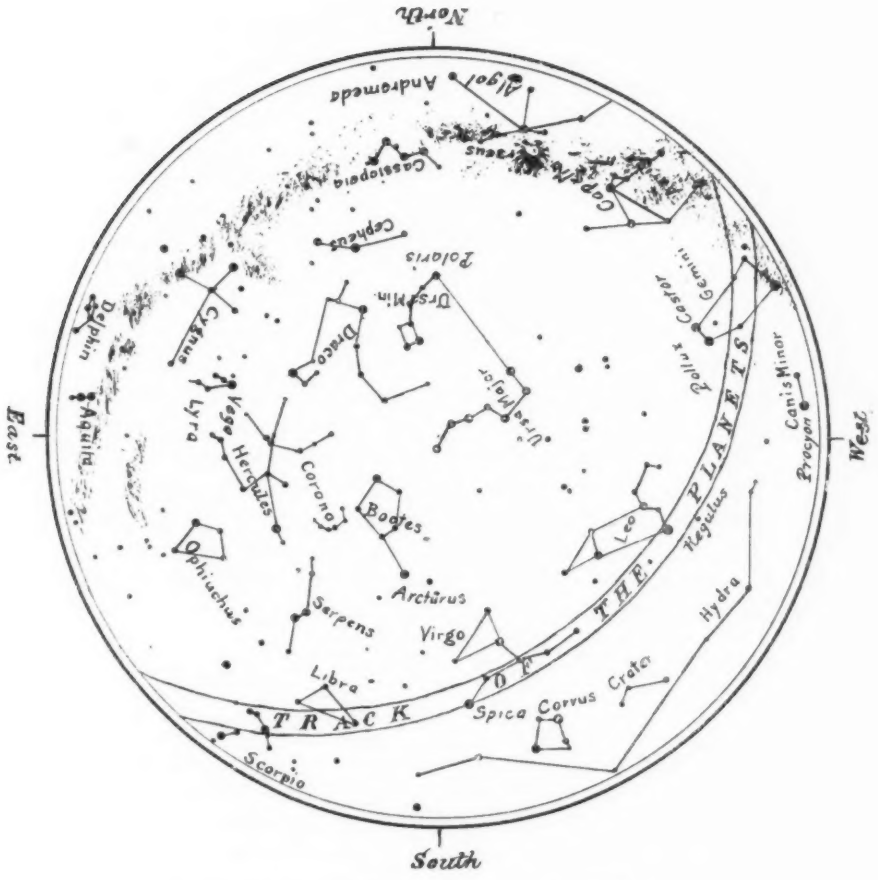
PREDICTIONS FOR MAY AND JUNE

PREPARED BY R. M. STEWART

The Constellations in May and June*

Since our last view of the evening sky the constellations have moved westward one-sixth of the circuit of the heavens. Those which were near the western horizon have been overtaken by the sun in his eastward march, and are now hidden in his rays, while others have risen in the east to take their place. The most conspicuous object in the sky is Jupiter, somewhat to the west of south and nearly half way up to the zenith. He is now in the western part of the zodiac constellation Virgo, close to the fourth magnitude star η Virginis. Some little distance to the southeast is Spica, the brightest star in Virgo; in the opposite direction at a little greater distance is the second magnitude star Denebola, in the constellation Leo; a little further yet is the well-known form of the Sickle, with Regulus, or Cor Leonis, at the extremity of the handle. Almost directly below Jupiter is the small constellation Corvus (The Crow), marked by two stars of the second magnitude, two of the third, and one of the fourth. The last (α Corvi) affords an example of the changes in brightness which some of the stars undergo even in limited periods of time; in Bayer's time, only three hundred years ago, this was probably the brightest star in the constellation. Such considerations as this may possibly afford some explanation of the fact that so few of the constellations now have the slightest resemblance in form to the objects whose names they were given in antiquity.

* As they appear at 9 p.m. on June 1; they may be located on other dates by remembering that a month earlier they are in the same positions (except the planets) at 11 p.m., and a month later at 7 p.m.



THE CONSTELLATIONS AT 7 P.M., JUNE 1

Much higher than Spica, and very slightly to the east of the meridian, is Arcturus, which is second in brightness only to Sirius and, perhaps, Vega. It forms a nearly equilateral triangle with Spica and Denebola, and may also easily be recognized by prolonging the sweep of the handle of the Dipper. A little further to the east, and at about the same altitude as Arcturus, is the pretty little half-circle of stars known as Corona Borealis, the Northern Crown; it contains only one star as bright as the second magnitude.

Somewhat to the north of east, and already well up towards the zenith, is Vega, one of the chief ornaments of our midsummer sky, flanked at nearly an equal distance on the remote side of the pole in the far northwest, by Capella. Southward from the latter, and approaching the northwestern horizon, are the twin stars Castor and Pollux, while slightly above them is the planet Mars. Low down in the north is Cassiopeia, and above it Ursa Minor and Ursa Major, the latter almost overhead. Polaris, which describes a diurnal circle of an apparent diameter only four or five times that of the moon, is now almost directly below the Pole. The exact position of the meridian can easily be observed by remembering that when Polaris and ζ Ursæ Majoris (the star next to the end of the handle of the Dipper) are in the same vertical plane, Polaris is in the meridian.

Mercury

On May 2 Mercury is at greatest elongation east of the sun; on account of its high declination this is one of the most favorable opportunities for seeing it. At sunset it is about 20° above the western horizon, and should be readily visible in the early evening for some little time before and after this date. It rapidly approaches the sun, being in inferior conjunction on May 25, after which it will be a morning star. Its greatest elongation west occurs on June 19, but this is a much less favorable one than the preceding, as it is at nearly its greatest distance south of the sun.

Venus and Saturn

During May and June Venus and Saturn are both visible in the morning sky. Venus maintains almost the same distance west of the sun, and hence is moving rapidly to the eastward among the stars, while Saturn's motion is much slower. They approach each other very closely on the morning of June 5, Venus passing about four minutes of arc to the north. The actual closest approach occurs about 9 a.m. Eastern Time, and can be seen only from points in the Pacific Ocean, where the sun has not yet risen. Even as seen here, however, the approach will be a remarkably close one. The moon is in conjunction with both planets a day earlier.

Jupiter

Jupiter is so nearly stationary during May and June that its whole motion does not exceed a degree and a half. During May its motion is towards the west, and during June towards the east. Though now receding from the earth, it is still a most interesting object, and, being high in the sky in the early evening, can be more conveniently studied by the amateur than at any other time. It is in conjunction with the moon on May 19 and June 15, and in quadrature with the sun on June 27.

Meridian Passage of the Principal Planets in May and June

LOCAL MEAN TIME

For May 15			For June 15
Mercury	12.52 P.M.	Taurus	12.40 A.M.
Venus	9.06 A.M.	Pisces, Aries, Taurus	9.16 A.M.
Mars	3.08 P.M.	Taurus, Gemini, Cancer	2.29 P.M.
Jupiter	8.49 P.M.	Virgo	6.47 P.M.
Saturn	10.24 A.M.	Aries	8.36 A.M.
Uranus	4.20 A.M.	Sagittarius	2.15 A.M.
Neptune	3.43 P.M.	Gemini	1.46 P.M.

Some Interesting Doubles Visible in Small Telescopes

γ Virginis. R. A. $12^h\ 37^m$; Dec. 0° 54′ S. One of the longest known of the binary systems, and observed as a double star for nearly 200 years. Yellowish. Period about 185 years. Magnitudes 3, 3. Very easy and fine. This wonderful pair has

been widening ever since they closed up beyond ordinary telescopic reach in 1836. Distance apart now 6″·2.

θ Virginis. R. A. 13h 5m; Dec. 5° 0′ S. A triple star, magnitudes 4·5, 9, 10; distances 7″ and 65″. The two brighter stars have been glimpsed with a 2¼-inch telescope and well seen with a 3-inch.

ε Bootis. R. A. 14h 41m; Dec. 27° 30′ N. Magnitudes 3, 6; distance 3″·1. Orange and greenish-blue. A beautiful pair and a well known test for small telescope. Webb saw it perfectly with a 2¼-inch, and a power 80 on a 3 7/10-inch divided it.

ζ Bootis. R. A. 14h 36m; Dec. 14° 9′ N. (About 9° southeast from Arcturus, at right angles to the line joining Arcturus and ε Bootis). Magnitudes 3·5, 4; distance 0″·8. A good test for a 4-inch glass.

β Lyræ. R. A. 18h 46m; Dec. 33° 15′ N. Has three small stars near it, forming a pretty object with a low power. The large star is variable, 3·4 to 4·5, with a period of 12d 21m.

ε Lyræ. R. A. 18h 41m; Dec. 39° 30′ N. The well-known "double-double." A sharp eye without telescopic aid splits the star, and a small telescope divides both components. The magnitudes of ε_1 are 6, 7; distance 3″·2; while ε_2 has magnitude 5·5, 6 and distance 2″·5. The distance between ε_1 and ε_2 is 207″.

δ Lyræ. R. A. 18h 51m; Dec. 36° 47′ N. This is a fine field for low powers.

λ Ophiuchi. R. A. 16h 26m; Dec. 2° 13′ N. This is a binary with a long period, the results given by various computers ranging from 89 to 373 years. Magnitudes 4, 6; distance 1″·2.

70 *Ophiuchi*. R. A. 18h 0m; Dec. 2° 32′ N. This is also a binary, and nearly one revolution has been made since the first measures of Struve. Period 86·7 years. Distance at present 2″·1. In 1850 the distance was 6″·7. It has been remarked that the rings about the telescopic image seem peculiar and observations are rendered more difficult on that account.

Clusters and Nebulæ

M.49. R. A. 12h 24m; Dec. 8° 40′ N. It forms an equilateral triangle with δ and ε Virginis. It lies in a remarkable

region abounding in nebulæ, most of them faint and observable only in large telescopes.

*M.*57. The Ring Nebula in Lyra. R. A. $18^h\,49^m$; Dec. 32° 53′. Between β and γ, one-third of the way from β. It is somewhat oval and bears magnifying well. Lord Rosse and others thought it resolvable into stars, but the spectroscope shows it to be luminous gas.

Bright broad group in Lyra at R. A. $18^h\,53^m$; Dec. 41° 56′ N. Between Lyra and Cygnus a pretty group at R. A. $18^h\,55^m$; Dec. 38° 7′.

*M.*23 in Ophiuchus. R. A. $17^h\,51^m$; Dec. 19° 0′ S. Fine low power field; about 100 stars from 9 to 13 magnitude.

*M.*13 in Hercules. R. A. $16^h\,38^m$; Dec. 36° 37′ N. Superb globular cluster, just visible to the naked eye. Finest of its class; discovered by Halley in 1714. Thousands of stars of magnitudes 10 to 15.

Radiant Points of Meteor Showers

For May and June the following are the meteor radiants: —

May 1, R. A. $15^h\,56^m$; Dec. 46° N., in Hercules, 3° W. of τ. Meteors small and short.

May 6, R. A. $22^h\,32^m$; Dec. 2° S., in Aquarius, near η. Rich shower visible before sunrise.

May 7, R. A. $16^h\,16^m$; Dec. 7° N., in Ophiuchus, 5° N. N. W. of λ. Meteors slow. Not very certain.

May 15, R. A. $19^h\,40^m$; Dec. 0°, in Aquila near η. Meteors swift with streaks and long paths.

May 30, R. A. $22^h\,12^m$; Dec. 27° N., in Pegasus 10° W. of β. Well defined; swift streak-leaving meteors.

June 7, R. A. $16^h\,28^m$; Dec. 25° S., in Scorpi 2° N. E. of α. Slow-moving.

June 13, R. A. $20^h\,40^m$; Dec. 61° N., in Cepheus close to η. Meteors very swift with streaks.

June 15, R. A. $19^h\,0^m$; Dec. 23° N. 8° W. S. W. of β Cygni. Meteors rather slow.

June 18, R. A. $20^h\,8^m$; Dec. 24° N., in Vulpecula.

June 20, R. A. $22^h\,20^m$; Dec. 57° N., in Cepheus close to δ. Meteors swift.

At Greenwich Mean Noon

Date 1910	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time Add to Mean Time	Sidereal Time
		h m s	° ′ ″	m s	h m s
Sun. 1	121	2 31 13·51	N. 14 53 30·4	2 54·74	2 34 8·25
Wed. 4	124	2 42 42·17	15 47 17·8	3 15·75	2 45 57·92
Sat. 7	127	2 54 15·96	16 38 45·2	3 31·62	2 57 47·58
Tues. 10	130	3 5 54·93	17 27 43·7	3 42·32	3 9 37·25
Fri. 13	133	3 17 39·01	18 14 4·3	3 47·91	3 21 26·92
Mon. 16	136	3 29 28·09	18 57 38·8	3 48·50	3 33 16·59
Thur. 19	139	3 41 22·13	19 38 19·6	3 44·13	3 45 6·26
Sun. 22	142	3 53 21·03	20 15 59·8	3 34·90	3 56 55·93
Wed. 25	145	4 5 24·66	20 50 33·0	3 20·94	4 8 45·60
Sat. 28	148	4 17 32·85	21 21 53·2	3 2·42	4 20 35·27
Tues. 31	151	4 29 45·40	21 49 54·8	2 39·55	4 32 24·95

75th Meridian Time, Hours numbering from Midnight

		Planetary Phenomena	Minima of Algol	Configuration of Jupiter's Satellites at 23h
			h m	
Sun.	1			1○234
☾ Mon.	2	8h 29·6m Last Quarter; 11h ☿ Greatest Elong E. 20° 55′.		2 1 2 3 ○ 4
Tues.	3		4 26	32○14
Wed.	4			31○24
Thur.	5	15h 41m ☌ ♀ ☾, ♀ 3° 54′ N.		32○41
Fri.	6		1 15	241○3
Sat.	7	18h 32m ☌ ♄ ☾, ♄ 0° 23′ N.		4○123
Sun.	8	14·4h ☾ in Perigee; ☉ total eclipse invis. in Canada.	22 4	41○23
☽ Mon.	9	0h 32·9m New Moon.		423○1
Tues.	10	7h 8m ☌ ☿ ☾, ☿ 1° 18′ N.		432○●
Wed.	11	2 1 in Aphelion.	18 53	431○2
Thur.	12	7h 46m ☌ ♂ ☾, ♂ 1° 57′ S.		2 1 4 3 ○ 1
Fri.	13	0h 51m ☌ ♆ ☾, ♆ 4° 39′ S.		214○3
Sat.	14	11h ☿ Stationary.	15 42	○2143
☽ Sun.	15	21h 13·1m First Quarter.		1○234
Mon.	16			2 1 2 ○ 1 4
Tues.	17		12 31	321○4
Wed.	18			31○24
Thur.	19	2h 7m ☌ 2 1 ☾, 2 1 3° 5′ S; 18h ☿ in ♉.		3○214
Fri.	20		9 20	21○34
Sat.	21	13·6h ☾ in Apogee.		○143●
Sun.	22			14○23
Mon.	23	☾ Total eclipse visible at Wash.	6 9	42○31
○ Tues.	24	0h 39·1m Full Moon.		4321○
Wed.	25	12h ☌ ☿ ☉ Inferior.		2 1 4 3 ○ 2
Thur.	26		2 58	43○21
Fri.	27	15h ♀ in Aphelion.		421○3
Sat.	28	6h 36m ☌ ♅ ☾, ♅ 3° 57′ N.	23 47	4○13●
Sun.	29	12h ☌ ♂ ♆, ♂ 1° 59′ N.		11○23
Mon.	30	23h ☿ in Aphelion.		24○31
☾ Tues.	31	17h 24·5m Last Quarter.	20 36	321○4

Key to Symbols.—☌ Conjunction; ☍ Opposition; □ Quadrature; ☊ Ascending Node; ☋ Descending Node; ☉ Sun; ☿ Mercury; ♀ Venus; ⊕ Earth; ♂ Mars; 2 1 Jupiter; ♄ Saturn; ♅ Uranus; ♆ Neptune.

AT GREENWICH MEAN NOON

Date 1910	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time Add to / Subt'd from Mean Time	Sidereal Time
		h m s	° ′ ″	m s	h m s
Wed. 1	152	4 33 50·49	N. 21 58 30·3	2 31·02	4 36 21·51
Sat. 4	155	4 46 8·29	22 21 58·7	2 2·88	4 48 11·18
Tues. 7	158	4 58 29·48	22 41 56·7	1 31·38	5 0 0·85
Fri. 10	161	5 10 53·40	22 58 19·5	0 57·12	5 11 50·52
Mon. 13	164	5 23 19·39	23 11 4·1	0 20·81	5 23 40·20
Thur. 16	167	5 35 46·80	23 20 7·7	0 16·92	5 35 29·88
Sun. 19	170	5 48 15·04	23 25 28·9	0 55·49	5 47 19·55
Wed. 22	173	6 0 43·54	23 27 7·2	1 34 32	5 59 9·22
Sat. 25	176	6 13 11·72	23 25 2·5	2 12·82	6 10 58·9
Tues. 28	179	6 25 39·05	23 19 15·7	2 50·48	6 22 48·57

75th Meridian Time, Hours numbering from Midnight

		Planetary Phenomena	Minima of Algol	Configuration of Jupiter's Satellites at 22h
			h m	
	Wed. 1			3○124
	Thur. 2	6h ♃ Stationary.		3○24●
	Fri. 3	[0° 2′ N.	17 25	21○34
	Sat. 4	7h 52m ☌ ☿ ☾, ☿ 0° 13′ N.; 9h 40m ☌ ♄ ☾, ♄		2○134
	Sun. 5	22·6h ☾ in Perigee; 9h ☌ ☿ ♄, ☿ 0° 4′ N.		1○234
	Mon. 6	6h 40m ☌ ☿ ☾, ☿ 4° 13′ S.; 15h ☿ Stationary.	14 14	2○134
●	Tues. 7	8h 16·4m New Moon.		231○4
	Wed. 8			34○12
	Thur. 9	12h 3m ☌ ♆ ☾, ♆ 4° 40′ S.; 23h 16m ☌ ♂ ☾,	11 3	431○2
	Fri. 10	[♂ 3° 6′ S.		♃423○
	Sat. 11			42○13
	Sun. 12		7 52	41○23
	Mon. 13			♃4○13
☽	Tues. 14	11h 19·4m First Quarter.		4213○
	Wed. 15	8h 56m ☌ ♃ ☾, ♃ 3° 9′ S.	4 41	34○21
	Thur. 16			31○42
	Fri. 17	11h ♂ Greatest Hel. Lat. N.		23○14
	Sat. 18	2·1h ☾ in Apogee.	1 30	2○34●
	Sun. 19	8h ☿ Greatest Hel. Lat. S.; 8h ☿ Greatest Hel. Lat.		1○234
	Mon. 20	[S.; 21h ☿ Greatest elongation W. 22° 48′.	22 19	○2134
	Tues. 21			213○4
♈	Wed. 22	15h 11·9m Full Moon; 3h ☉ enters ♋; Summer com.		3○14●
	Thur. 23		19 8	31○24
	Fri. 24	10h 57m ☌ ♁ ☾. ♁ 3° 50′ N.		23○41
	Sat. 25			42○3●
	Sun. 26		15 57	41○23
	Mon. 27			4○213
	Tues. 28	0h □ ♃ ☉.		♃421○
☾	Wed. 29	23h 38 9m Last Quarter.	12 46	43○1●
	Thur. 30			431○2

For Jupiter's Satellites, the circle ○ represents the disc of the planet; ♃ signifies that the satellite is on the disc; ● signifies that the satellite is behind the disc or in the shadow. Configurations are for an inverting telescope.

ECLIPSES AND TRANSITS OF THE SATELLITES OF JUPITER

E = eclipse, O = occultation, T = transit, S = shadow, D = disappearance, R = re-appearance, I = ingress, e = egress.

Eastern Standard Time; hours numbering from midnight.

MAY

d	h	m			d	h	m			d	h	m		
2	1	16	I.	OD	**10**	1	13	I.	SI	**18**	21	36	I.	SI
	20	55	III.	Se		2	36	I.	TE		22	51	I.	Te
	22	34	I.	TI		21	29	I.	OD		23	51	I.	Se
	23	18	I.	SI	**11**	0	34	I.	ER	**19**	20	57	I.	ER
3	0	48	I.	Te		19	41	I.	SI		23	31	II.	TI
	1	33	I.	Se		21	3	I.	Te	**20**	1	32	II.	SI
	19	42	I.	OD		21	56	I.	Se	**21**	23	18	II.	ER
	22	40	I.	ER	**12**	21	9	II.	TI	**25**	1	6	I.	OD
4	0	35	II.	OD		22	57	II.	SI		22	36	I.	TI
	20	1	I.	Se		23	50	II.	Te		23	31	I.	SI
5	20	32	II.	SI	**13**	1	39	II.	Se	**26**	0	41	I.	Te
	21	30	II.	Te	**14**	20	41	II.	ER		22	52	I.	ER
	23	4	II.	Se	**16**	22	28	III.	TI	**27**	20	14	I.	Se
9	21	25	III.	Te	**17**	0	59	III.	Te		20	30	III.	ED
	22	27	III.	SI		2	9	I.	TI		22	40	III.	ER
10	0	21	I.	TI		23	17	I.	OD	**28**	20	59	II.	OD
	0	53	III.	Se	**18**	20	36	I.	TI	**30**	20	7	II.	Se

JUNE

d	h	m			d	h	m			d	h	m		
2	0	16	I.	TI	**10**	20	36	I.	TI	**17**	23	45	I.	SI
	21	24	I.	OD		21	50	I.	SI	**18**	23	5	I.	ER
3	0	46	I.	ER		22	51	I.	Te	**19**	20	28	I.	Se
	19	55	I.	SI		23	18	III.	OD	**20**	22	39	II.	TI
	20	59	I.	Te	**11**	0	4	I.	Se	**21**	22	24	III.	SI
	22	8	III.	OR		21	0	I.	ER	**22**	23	1	II.	ER
	22	9	I.	Se	**13**	20	8	II.	TI	**25**	21	31	I.	OD
4	0	30	III.	ED		22	37	II.	SI	**25**	20	8	I.	SI
	23	27	II.	OD		22	50	II.	Te		21	7	I.	Te
6	20	1	II.	SI	**14**	20	44	III.	Se		22	33	I.	Se
	20	20	II.	Te	**15**	20	25	II.	ER	**28**	21	4	III.	TI
	22	42	II.	Se	**17**	22	29	I.	TI	**29**	20	24	II.	OD
9	23	16	I.	OD										

OCCULTATIONS OF STARS BY THE MOON*

Date		Star	Mag.	Time				Position Angle	
				Immersion		Emersion		Immersion	Emersion
1910				h	m.	h	m	°	°
May	19	46 *Virginis*	6·1	10	18·7	11	38·2	183	279
"	19	48 *Virginis*	6·5	12	40·7	13	44·2	96	323
"	22	26 *Librae*	6·3	10	38·7	11	17·7	56	1
"	24	88 *B Ophiuchi*	6·3	14	33·7	15	52·2	85	293
"	24	26 *B Ophiuchi*	5·8	14	48·9	15	46·9	55	324
June	12	46 *Leonis*	5·8	10	11·1	10	53·1	74	340
"	20	126 *B Scorpii*	6·1	13	0·9	13	52·9	150	230
"	21	136 *G Ophiuchi*	6·3	7	38·6	8	49·1	94	301
"	21	151 *G Ophiuchi*	6·0	9	32·6	11	4·1	94	290
"	23	248 *B Sagittarii*	5·7	14	24·9	15	10·9	135	204
"	25	35 *Capricorni*	6·0	17	53·3	18	42·8	107	200

*Prepared by R. M. Motherwell for the Dominion Observatory, Ottawa.